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Prepared for:
U.S. Army Intelligence and Security Command
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U.S. DEPARTMENT OF COMMERCE, Clarence J. Brown, *Acting Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

Because many military and civilian employees of the U.S. Army are required to work in environments unlike those experienced by most civilian workers, a project involving a comprehensive assessment of such workplaces was initiated. This assessment involves a two-phase effort in which the first phase consisted of a literature search, interviews with experts, site visits, and limited field environmental measurements. The second phase will include a comprehensive assessment of environmental conditions including lighting at selected military facilities. The present report documents findings from phase 1, including a detailed bibliography of target areas: lighting, stress, and shiftwork. It also includes preliminary results from a visit to two military field stations. During each visit, selected individuals, including supervisory, operational, analytical, and maintenance personnel, were interviewed to determine their view of the environmental conditions. At the same time, limited field measurements were made, including lighting, noise, temperature, humidity, and particle counts (at site 2 only). Preliminary data and recommendations are presented.

Keywords:

Automation, contrast, environmental assessment, indoor air quality, lighting, luminance, noise, post-occupancy evaluation, temperature, VDT's.

FOREWORD

This report is the first in a series documenting National Bureau of Standards (NBS) research and analyses efforts in support of the Army Intelligence and Security Command (INSCOM) program on field station environmental assessment. This report is a deliverable product for Phase 1.

The report summarizes research conducted from August 1986 to 1987.

We wish to acknowledge with special thanks, the interest, cooperation, and encouragement of the sponsor and the field station personnel during all aspects of the project.

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EXECUTIVE SUMMARY

Many military and civilian employees of the U.S. Army are required to work in environments unlike those experienced by most civilian workers. A project involving a comprehensive assessment of such environments was therefore initiated. This assessment involves a two-phase effort in which the first phase consisted of a literature search, interviews with experts, site visits, and limited field environmental measurements. The second phase will include a comprehensive assessment of environmental conditions including lighting at selected military facilities.

During the first phase, a literature search was initiated in three target areas - lighting, stress, and shiftwork. All are thought to influence job performance. The references listed at the end of the present report were identified and obtained as part of this effort.

In addition, in the first phase of the project, two military field stations were visited to gain an understanding of the types of environments typical in such facilities. Both were windowless, housing extensive automated equipment, including Video Display Terminals (VDT's) typically in an open-office arrangement. Site 1 consisted of two small buildings, while site 2 consisted of a large underground facility. During each visit, selected individuals, including supervisory, operational, analytical, and maintenance personnel were interviewed to determine their view of the environmental conditions. At the same time, limited field measurements were made, including lighting, noise, temperature, humidity, and air particle counts (at site 2 only).

Conversations during the interviews indicated problems with lighting (particularly in the VDT areas), temperature, air quality (particularly at site 2), furniture condition (particularly chairs), condition and maintenance of HVAC equipment, overall quality of the space, and need for break areas for non-smokers and improved spaces for smokers.

Preliminary environmental measurement data from the site visits are presented. Initial results suggest that lighting is a major problem at both sites, partially because of the mix of VDT and paper tasks, although the problems are more pronounced at site 2. Here, light levels in the areas where VDT's are used are very low - around 70 lux (7 fc) - well below IES (Illuminating Engineering Society) recommendations of 200 to 1000 lux for reading printed material in offices. Yet, problems of lowered contrast, specular reflections, and glare on the VDT screen due to the light sources themselves are common, particularly when the light levels are raised to about 200 lux. At this level, paper tasks can easily be read - but VDT tasks become more difficult. Yet, people

reading paper copy complain that they cannot see at the lower levels.

Further research will document the extent of problems with screen contrast, luminaire placement, and diffuser type. Other environmental problems included noise, particularly from printers and air handlers, HVAC outages at site 1, high humidities and low temperatures which were outside the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) comfort recommendations at site 2, and problems with dust and mold at site 2.

Based on the interviews and preliminary data, recommendations for some immediate changes are presented. In addition, a research plan for determining the magnitude and relative importance of different environmental features is presented. In the final report, guidelines for designing or altering military office spaces such as these will be presented, based on the results of the detailed environmental assessment.

1. BACKGROUND

Many military and civilian employees of the U.S. Army are required to work in environments unlike those experienced by most workers. These are characterized by windowless spaces, highly automated equipment, and work tasks that require utmost concentration. These conditions have led to employee complaints concerning lighting, air quality, thermal environmental conditions, lack of view to the outside and rotating work schedules that add stress to an already complex work situation.

The working conditions described are thought to detract from the job performance of the staff, and guidelines are sought for environmental changes to ameliorate the problems identified.

Noise, lighting, temperature, humidity and indoor air quality constitute important measures of the indoor environment. Noise guidelines have been set generally by the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA). Typically, these refer to the amount of time a person can be exposed to a noise source without suffering hearing damage but do not deal with the stressful effects of lower levels of noise.

Lighting levels are not covered by regulations such as the OSHA noise levels. Nonetheless, the Illuminating Engineering Society of North America (IESNA) and the Commission Internationale de l'Eclairage (CIE) have made recommendations about lighting levels for tasks based on research into visual performance. Similarly ASHRAE has developed guidelines for indoor temperature and humidity based on research into human comfort, and is developing guidelines for indoor air quality. EPA and others are working on regulating indoor air quality, as well. (Certain aspects of indoor air quality have been covered for years under mining and industrial regulations limiting exposure to harmful chemicals, etc.)

1.1 <u>OBJECTIVES</u>

The objectives of the study are:

1. To determine the specific nature of the general problems cited by the U.S. Army.

2. To plan and conduct a research investigation to gather quantitative data concerning the problems.

3. To propose design guidelines and/or other means of implementing the findings of the study.

1.2 TECHNICAL APPROACH

The study is being performed in two phases. The first phase, reported here, consisted of a literature search, interviews with experts, and planning and conducting a pilot study at a limited number of field sites. The second phase will be a comprehensive field investigation at a sample of additional sites, including field measurements of lighting, air quality, noise etc.

1.3 PHASE 1

The primary purposes of phase 1 were to gain a better understanding of existing environmental problems, develop, test, and refine data collection methods, and plan for the major study in phase 2. The specific tasks accomplished were:

1. Conduct a literature search of relevant research.
2. Plan, test, and refine data collection methodologies for initial field studies.
3. Conduct pilot studies at two field locations.
4. Evaluate findings of above and submit a detailed research plan for phase 2.

1.4 PHASE 2

The environmental assessment of phase 2 will consist of a comprehensive evaluation of physical conditions such as lighting, noise, temperature, humidity, space and (limited) air quality, and the user responses to these conditions. An analysis of the tasks performed at the site will also be undertaken to determine the effect of environmental and other design factors on work performance. User response data will be obtained in two ways: in-depth personal interviews with key people; and a detailed environmental questionnaire of a representative sample of site personnel. The phase 2 tasks are to:

1. Conduct a "full fledged" field study (physical and performance measures) at a sample of field sites. The specific study design will be based upon the findings obtained during phase 1.
2. Complete the general literature search initiated in phase 1, including evaluations of environmental and duty cycle conditions on job performance.
3. Complete a design guideline, and suggest other means of upgrading work conditions; e.g. demonstration studies.

1.5 SHORT TERM RECOMMENDATIONS (IMMEDIATE ACTIONS POSSIBLE)

During phase 1, two field stations were visited. Site 1 consisted of two windowless buildings above ground. Site 2 was an underground facility reached by a long tunnel (approximately 1/4 mile long). At the two sites, several general types of problems were identified: lighting, air quality, noise, furniture condition, space, and maintenance. For some of the issues identified, preliminary recommendations follow. Data collected during phase 2 will be used as a basis for more extensive recommendations.

1.5.1 Lighting

Problem: Many different types of lamps and fixtures are in the facility, often several in the same space.

Recommendation: Lamp and fixture uniformity will improve general office appearance and greatly simplify inventory requirements.

Problem: The resolution of many CRT screens is a source of concern because they are hard to read; some are quite old.

Recommendation: Replace obsolete equipment.

Problem: Lighting Conditions are inadequate to support VDT and paper tasks in some locations.

Recommendation: In the operations and analysis areas, task lighting,(a small lamp used to light the paper copy) might be useful, leaving the ambient lighting at a relatively low level. On the operations floor, another possibility is the use of supplementary up-lighting to light the ceiling but not prodance glare on the VDT screens. This would allow the overall levels to remain low yet provide some visual interest to the space. Still another solution is greater use of parabolic fixtures to direct the light on the task while minimizing glare.

Problem: Glare on the VDT screens.

Recommendation: The desks ought to be located so no lamps are directly in front of the occupants or directly behind them if they are using VDT's.

1.5.2 Air Quality

Problem: Diesel fumes are in enclosed areas, caused by truck travel in the tunnel.

Recommendation: One approach would be to ban all trucks from idling their motors while in the tunnel, and to ban vehicular movement in the tunnel during shift change. A more permanent

solution would probably involve exhausting the air from the tunnel as part of the overall air handling system design. This capability should be included in any air conditioning upgrade.

Problem: Break areas are filled with smoke.

Recommendation: Air cleaners should be placed in the break areas.

1.5.3 Noise

Problem: Noise interference with tasks.

Recommendation: For printers, covers would provide some protection from noise.

Problem: Noise produced from air handlers

Recommendation: Limit the number of personnel located near them.

1.5.4 Maintenance

Problem: Much of the facility could stand painting.

Recommendation: Painting the walls using a variety of colors, and murals, borders, or pictures, is likely to improve the appearance of the overall work environment.

1.5.5 Furniture

Problem: Many chairs are unsuitable for the tasks being performed.

Recommendation: Durable, ergonomic chairs should be employed. They should be similar to those used by FAA controllers. A limited number of them could be tested to determine whether they will overcome the deficiencies noted in the chairs presently used by military personnel.

2. INTRODUCTION

Two facilities staffed by the U.S. Army and other armed services were studied as the first phase of a research effort. Both are windowless and house considerable amounts of electronic and automated office equipment. At the first site (Site 1), two buildings in an above-ground location were visited briefly to gain some understanding of the types of tasks, equipment, and general conditions typical of such facilities. At the second site (Site 2), an underground facility, a more detailed evaluation was made.

Phase 2 of this study will consist of a more detailed investigation of Site 2, including a questionnaire survey, and investigations at two more sites, where similar activities are performed.

These preliminary data are discussed in the following sections.

3. EVALUATION OF SITE 1

The two buildings at Site 1 suggest warehouses converted for new uses. The original structure and building systems such as ducts, wiring, etc., are very much in evidence. As a result, the work setting appears to be somewhat makeshift, with equipment, furniture, and people placed wherever there is room to accommodate them. This is particularly true in the first building, currently under reconstruction, yet operational.

3.1 GENERAL COMMENTS

The heating, air conditioning, and electrical power systems were modified (generally downsized) from the original design. Because the equipment and personnel loading are much higher than the modified design, environmental problems are common. For example, work is frequently halted when the temperature exceeds the level required for equipment to operate properly. In other cases, large fans added to circulate air contribute considerably to the overall noise level.

Uniform temperature and air movement conditions in the buildings are difficult to achieve, since the original systems were designed for warehouse operations. As a result, temperatures in many spaces vary from being too hot or too cold, while stagnant air was mentioned as a problem by several respondents. These latter problems were more severe in office areas, where administrative functions are separated by space dividers or located in private offices. The appropriate balancing of heating, air conditioning and air flow systems was said to be an ever-present problem.

3.2 LIGHTING SYSTEMS

The lighting system consisted of fluorescent 2 x 4 fixtures with only two 40 watt lamps operational. Although light sources were generally daylight fluorescent, some had been occasionally replaced with cool white lamps, giving the ceiling a checkerboard appearance. In the first building, eggcrate diffusers were used in a recessed housing. During the study many lamps were non-functional due to outages or the desire to reduce screen glare. In the first building, several lamps were flickering, indicating the need for lamp or ballast replacement. Diffusers were also quite dirty, probably because of the construction occurring at one end of the building.

Timely relamping appeared to be a major problem in the first building, exacerbated perhaps by the on - going renovations. While lamp replacement is regularly scheduled, interview findings indicated this procedure was not effective. When lamps burn out, affected workers inform maintenance personnel responsible for replacing lamps. Considerable time often elapses between the notification of a burnt-out lamp, and its replacement.

In the newly renovated space, special non-glare luminaires using parabolic diffusers were being installed. Each lamp in a fixture can be controlled by individual operators. Without equipment or people in the space, these fixtures appeared to reduce problems of glare and unevenly lit areas. On initial examination, this lighting system appeared to be effective for most VDT based tasks.

In the second building, a pendant-mounted 2-lamp fixture with no diffuser was employed. The general impression was of higher light levels with a harsh, glaring appearance. The daylight fluorescent lamps added to the starkness of the environment, since the desks and equipment were mostly gray. The use of cool white replacement lamps for daylight fluorescent was particularly obvious here. Since there were fewer VDT screens, no screen glare problems were observed. (Detailed measures of selected lighting installations are presented in section 2.2)

3.3 ACOUSTIC CONDITIONS

Many key activities performed at workstations at both sites were extremely noise sensitive. They are based on aural communications of various types, with the information received often embedded in electronic noise. Significant environmental noise sources made the task much more difficult; the signal-to-noise ratios were often significantly degraded. Under these circumstances, there are three likely outcomes:

1. It takes longer to perform the task.
2. There are likely to be more operator errors.

3. Performing work under these conditions is very difficult, stressful and demanding for the worker.

The noise problem was intensified by the "hard" surfaces of the walls and metal equipment racks, and the lack of soft surfaces (such as fabric dividers or curtains) that might absorb sound. The equipment, walls, and floors all reflect sound, resulting in a workspace that in many ways acts as a reverberation room. As a result, overall sound levels approached those produced by the major noise sources within the space. In short, instead of minimizing the detrimental effects of noise, the space design maximizes them.

Another problem was that the noise producing equipment do not have acoustical treatment (such as printer covers) which could significantly reduce the sound level locally, and in the general environment.

3.4 WORKSTATION ISSUES

All activities other than administrative and some supervisory functions were conducted in open space areas. Panels or other dividers were not used between operators or analysts. Working conditions appeared to be quite crowded, particularly in the first building.

The size and configuration of the individual workstations were largely dictated by the equipment used by operators. They were abutted together, with minimal room for anything but materials being worked on at a given time. Operators work side-by-side in several rows. There was no place for personal items, which intensifies the factory-like appearance of the setting.

The analysts also worked in an open setting, with no separation between people. The analysts had private desks, not surrounded by electronic equipment thereby enjoying more immediate work area space than operators, but space remained at a premium. The nature of their tasks, requiring considerable thought and concentration, suggests the need for more privacy and acoustic separation.

3.5 OTHER ISSUES

The quality of the break areas was a frequently raised concern. The current break area in the first building is a small room shared by smokers and non-smokers which houses soda and candy machines. In the second building the break area is located on a renovated loading dock and is quite uncomfortable in the rain or cold. While perhaps adequate for a quick break, these areas are not suitable for meals, although used for this purpose when the main dining facility is closed. Operators expressed the desire

for an attractive break area to get away from their work, if only briefly.

Corridors in the facility, particularly building 1, were quite narrow, barely permitting passage for two people walking in opposite directions. They offered little opportunity for casual conversation without severely disrupting traffic.

Still another issue is the nondescript appearance of the facility. The walls are painted in pastel colors (often yellow or buff); much of the furniture is gray metal; no dividers are used; and there are no windows. The lighting is daylight fluorescent which contributes to the "cold" appearance of the facility. In one area, however, murals had been painted on two walls in general view of the operators. Several people commented favorably on this touch of interest and color and expressed a desire for more.

3.6 ENVIRONMENTAL MEASURES AT SITE 1

During the visit to Site 1 a limited number of lighting and noise measurements was made to characterize some of the physical conditions in the two buildings, and to test procedures and instrumentation to be used in the later study.

3.6.1 Lighting Measurements

Lighting measures consisted of measures of illuminance and luminance for both a paper task and VDT screen. These measures are given in table 1. In addition, contrast, or the ratio between the task and surround luminance, was also calculated.

As noted earlier, in the first building at Site 1, two fluorescent lamps were used in a 4 lamp recessed fixture with eggcrate diffusers. (In many areas, dirt was visible on the louvers.) In this area, 40-watt daylight lamps were used. Fixtures were located about every 5 to 6 ft. Most of the VDT screens had anti-reflective screens on them. Despite these screens, in a number of cases, the luminaire could be seen imaged on the VDT screen. In the second building, 2 40-watt daylight fluorescent lamps were again used, this time in a pendant mounted fixture with no diffusers. Here, the lamps were suspended directly below a curved reflector.

Table 1. Lighting Measurements at Site 1

Table 1A. Measured Illuminance and Luminance

Operations 1

Area	Type	Illum. Lux	Luminance in cd/m2 White Paper	Task	Desk	VDT Keybrd	VDT Screen	VDT Char	Lamp	Ceiling
1	DESK	107.6	30.5		3.0					
2	DESK	182.9	53.4		5.8				1911.7	7.5
1	VDT	53.8	5.1	0.5		3.0	3.0	10.0		
2	VDT	161.4	28.8			25.4	0.5	4.2	589.3	8.7
3	DESK	193.7								
4	VDT	129.1					2.0	9.6	582.4	5.0
5	VDT	64.6					0.7	10.1		
6	VDT	129.1	27.7		5.8	1.8	1.6	11.9	2627.7	4.2
7	VDT	96.8	27.0		5.2	1.1	0.6	14.3	56.2	1.1
8	VDT	129.1	13.8		5.1	1.0	1.4	9.7	579.0	4.9
9	DESK	269.0	65.1	6.0	48.6	0.0	0.0	0.0	674.9	11.2
	MEAN	137.9	31.4	3.2	12.3	6.5	1.4	10.0	1003.0	5.4
	STD	58.9	18.3	2.8	16.3	9.5	0.8	2.8	844.9	3.4

Analysis 1

Area	Type	Illum. Lux	Luminance in cd/m2 White Paper	Task	Desk	VDT Keybrd	VDT Screen	VDT Char	Lamp	Ceiling
1	DESK	269.0	79.8		10.1				0.0	5.9
2	DESK	441.2	144.2	12.5	19.3				688.6	25.1
3	DESK	548.8	126.8		100.4		5.0	27.2	681.8	23.9
4	DESK	559.5	143.2	27.8	10.3				2648.3	27.4
5	DESK	247.5	75.7	5.1	51.7				671.5	13.6
6	DESK	193.7	53.1	4.8	6.8				558.4	10.1
7	DESK	107.6	26.5	1.1	17.6				637.2	7.1
	MEAN	338.2	92.8	10.3	30.9		5.0	27.2	981.0	16.2
	STD	165.2	42.7	9.5	31.6				746.9	8.4

Redesigned Area with Parabolic Fixtures

Area	Type	Illum. Lux	Luminance in cd/m2 White Paper	Task	Desk	VDT Keybrd	VDT Screen	VDT Char	Lamp	Ceiling
1	DESK	376.6	108.9	8.7	65.8				376.9	32.0
2	DESK	333.6	108.6	11.6	166.8				1586.2	19.7
	MEAN	355.1	108.8	10.2	116.3				981.5	25.8
	STD	21.5	0.2	1.5	50.5				604.7	6.1

Table 1. Continued

Analysis 2

Area	Type	Illum. Lux	Luminance in cd/m2 White Paper	Task	Desk	VDT Keybrd	VDT Screen	VDT Char	Lamp	Ceiling
1	DESK	226.0	66.1	4.9	11.8				664.6	14.8
2	DESK	226.0	64.1	6.2	6.0				561.9	14.1
3	DESK	312.0	89.8	6.3	12.5				544.7	19.2
4	DESK	301.3	73.7	5.2	11.5				572.1	19.0
5	VDT	312.0	96.6	8.3	9.1	58.6	2.4	18.5	0.0	0.0
	MEAN	275.5	78.0	6.2	10.2	58.6	2.4	18.5	585.8	16.8
	STD	40.6	13.0	1.2	2.4				46.5	2.3

Operations 2

Area	Type	Illum. Lux	Luminance in cd/m2 White Paper	Task	Desk	VDT Keybrd	VDT Screen	VDT Char	Lamp	Ceiling
1	DESK	139.9	37.3	2.2	12.8				493.3	7.6
2	DESK	193.7	54.1	2.6	14.1				1010.7	8.5
3	DESK	161.4	46.6	2.1	14.5				507.0	6.7
4	DESK	118.4	33.5	1.5	17.8				568.7	4.3
5	DESK	193.7	37.3	1.8	14.7	5.1			623.5	6.0
	MEAN	161.4	41.8	2.0	14.8	5.1			640.7	6.6
	STD	29.7	7.5	0.4	1.6				190.8	1.4

Table 1B. Calculated Contrast and Contrast Ratios at Site 1

Area	Lux	Operations 1 Contrast Ratio	Contrast	Contrast Ratio	Contrast
1	107.6				
2	182.9				
1	53.8	10.6	0.91	3.4	0.70
2	161.4			8.2	0.88
3	193.7				
4	129.1			4.8	0.79
5	64.6			15.6	0.94
6	129.1			7.4	0.86
7	96.8			23.2	0.96
8	129.1			6.9	0.86
9	269.0	10.9	0.91		
	137.9	9.7	0.90		0.86
	58.9	6.6	0.85	3.4	0.70

Table 1. Continued

Analysis 1

Area	Lux	Contrast Ratio	Contrast	Contrast Ratio	Contrast
1	269.0				
2	441.2	11.5	0.91		
3	548.8				0.82
4	559.5	5.1	0.81		
5	247.5	14.9	0.93		
6	193.7	11.2	0.91		
7	107.6	23.5	0.96		
	338.2	9.0	0.89	0.2	0.82
	165.2	4.5	0.78		

Redesigned Area with Parabolic Fixtures

Area	Lux	Contrast Ratio	Contrast	Contrast Ratio	Contrast
1	376.6	12.6	0.92		
2	333.6	9.3	0.89		
	355.1	10.7	0.91		
	21.5	0.1	6.50		

Analysis 2

Area	Lux	Contrast Ratio	Contrast	Contrast Ratio	Contrast
1	226.0	13.4	0.93		
2	226.0	10.3	0.90		
3	312.0		0.93		
4	301.3	14.1	0.93		
5	312.0	11.6	0.91	7.8	0.87
	275.5	12.6	0.92	7.8	0.87
	40.6	10.9	0.91		

Operations 2

Area	Lux	Contrast Ratio	Contrast	Contrast Ratio	Contrast
1	139.9	17.0	0.94		
2	193.7	21.1	0.95		
3	161.4		0.96		
4	118.4	22.3	0.96		
5	193.7	20.6	0.95		
	161.4	20.5	0.95		
	29.7	21.0	0.95		

Inspection of table 1 reveals that for the operations area in the first building at Site 1, the mean illuminance was 138 lux (12.8 fc). Screen contrast was calculated to be 0.86. The mean lamp luminance was 1003 cd/m^2. In the first analysis area at Site 1, mean illuminance was 338 lux (31.4 fc). Only one VDT was measured in this location, so only the paper task contrasts could be calculated as shown at the bottom of table 1. Mean lamp luminance was 981 cd/m^2 for this area.

One area at Site 1 had been redesigned with parabolic fixtures, and individual dimming switches (as well as with raised floors and improved air conditioning.) Parabolic fixtures are designed to direct the light directly down, with relatively little spill into adjacent areas. Since this area had not yet been occupied, no data are available on VDT luminances. Data taken for a paper task indicate that both illuminance and contrast were relatively high, 335 lux (33 fc) and 0.90, respectively. In this area lamp luminance (and illuminance on the task) varied considerably depending on the position of the light meter relative to the diffuser.

Additional lighting measurements were taken at both operator and analyst stations in the second building at Site 1. As noted earlier, the lighting here was from pendant-mounted bare fixtures, with a reflector mounted behind the two fluorescent lamps and no diffuser.

In the second building, the mean illuminance was somewhat lower than in the first building for the analytical areas, 276 lux (35.6 fc); but higher for the operational areas, 161 lux (15 fc). Mean luminances for the white paper were 78 cd/m^2 and 41.8 cd/m^2, respectively. Calculated contrasts for both areas were slightly higher than in the first building. Data were obtained for only one VDT unit (since they were infrequently used in this building), making it impossible to draw any conclusions about the effect of room lighting on VDT's. Mean lamp luminances were quite low. The standard deviations of lamp luminance were also much smaller, since measurements did not have to be taken through diffusers. Ceiling luminances were actually higher than in the first building.

The overall lighting in the second building appeared very harsh and glaring, perhaps because of the bare fluorescent lamps. The combination of daylight fluorescent, a very blue-white light, with the gray metal furniture increased the overall sensation of harsh, bright lighting.

During informal discussion with operations staff and analysts, no complaints about the lighting or the general environmental conditions emerged. The only complaints noted were the frequent air conditioning outages, which resulted in work stoppages. As for lighting, levels appeared to be low but comfortable on the

operations floor. The use of generally low light levels, anti-reflective screens, and reasonably effective positioning of light sources relative to the operator's tasks may have contributed to this outcome. The brevity of discussions with operators may have also contributed to a lack of complaints, however.

3.6.2 Acoustic Measurements

A limited set of measurements was made to determine the noise levels in and around the building. This was not a formal survey, but a pilot investigation to determine if noise problems are likely at other sites. The measurements indicated that in the major task area, the general environment was quite noisy (between 64 and 72 dBA) with many noise sources such as printers and air handlers concentrated in confined areas. These levels are likely to interfere with many key tasks, but do not pose any medical threat such as permanent hearing impairment.

4. EVALUATION OF SITE 2

4.1 GENERAL COMMENTS

The facility at Site 2 is a 40-year old building located 60 ft underground. Personnel work in eight hour shifts around the clock. The HVAC system is old and unreliable, as is the standby power system. Planned upgrades have been delayed due to excessively high cost estimates. Lighting is a major concern-it is dark at the VDT consoles, Lamps have been removed to respond to complaints about glare, yet printed copy must also be read at these locations.

At present, major alterations are being planned for the air conditioning and power systems, and for about half of the offices (including raised flooring, dropped ceilings, more space, etc. This latter modification is at the 35% design stage). Another area of 9000 sq ft has recently been refurbished with raised flooring, new lighting, fresh paint and wall graphics.

Extensive tape recorded interviews were made with operational and building management personnel. (Summaries are in Appendix C.) These interviews dealt with environmental problem areas, design issues, ergonomics and work performance. The goal was to determine key problem areas to be addressed in detail during phase 2, which will employ physical measurement techniques and questionnaire survey instruments.

Based on the taped in-depth interviews, informal discussions, accompanied "walk-thru's", environmental measurements, and direct observations, a number of problem areas emerged at Site 2. In this report suggestions have been made to alleviate particular problems where available information appears sufficient to deal with them; i.e. issues not requiring extensive data collection during phase 2. Many of these recommendations were presented in section 1.5.

4.1.1 Air Conditioning System

Perhaps one of most important problems cited at Site 2 is that of the air conditioning/air handling system. Its poor performance in dehumidifying and cleaning the air suggests it might be responsible for some health-related problems at the site. Problems of mold and mildew abound; black dirt is evident on desks and light surfaces; and complaints about illness (particularly on arrival at the site) are fairly frequent. The source of the black dirt is not known, although the frequent burning of fields outside is a conceivable contributor. Failure to maintain and operate the air handling equipment properly before and during its transition to its current use may also have contributed to the problems.

Conversations with the personnel responsible for the system suggest that maintenance - or the lack thereof - might be at the root of some problems. The air is not properly conditioned before being brought into the tunnel, making humidity control much more difficult. The failure to perform routine monthly, quarterly, or yearly maintenance (due apparently to inadequate staffing) results in dirt, poor equipment performance, and premature equipment failure. The "quick fix" proposed solutions such as adding individual room conditioning equipment have not solved the overall problem of inadequate air conditioning and may be responsible for many complaints about cold temperatures on the operations floor. It is anticipated that the planned air conditioning upgrade will overcome these difficulties.

4.1.2 Air Quality

Problems with the HVAC equipment have also led to complaints about overall air quality. The smoking ban has improved the overall air quality, although existing smoking areas provoked many unfavorable comments. Many people cited the improved conditions since smoking was banned on the operations floor. Another problem raised was that of diesel exhaust from trucks in the tunnel.

Recommendations:

* One solution to the exhaust problem would be to ban all trucks from idling their motors while in the tunnel, and to ban vehicular movement in the tunnel during shift change. More permanent solution of the problem of diesel fumes would probably involve exhausting the air from the tunnel as part of the overall air handling system design. This capability should be included in any air conditioning upgrade.

4.1.3 Space Issues

Another major cause for concern was space limitations, said to adversely affect the work of analysts in particular. Regardless of the service branch, analysts commented on the number of distractions, overall noise levels, and difficulty performing some of their work. They reported being able to perform routine tasks, but having difficulty performing tasks requiring greater attention and concentration. Analysts sit side-by-side with a standard (about 30" by 60") desk as their work surface. Often, if they back up too quickly from their desk, they encounter another person. Their jobs sometimes requires consultation with colleagues creating distractions for those not directly involved in the activity. Finally, people walk through their offices, routinely carrying on conversations, causing further distractions. They have no separate conference rooms or training facilities.

4.1.4 Lighting

Lighting emerged as a major problem, particularly on the operations floor. The light levels achieved when the room lights are all on - 19 to 20 fc (190 - 200 lux) - led to extensive complaints about glare. As a result room lights are routinely turned off - resulting in a light level of about 7 fc (70 lux). Current IES recommendations for areas with VDT screens range from 50 to 100 lux. (IESNA, 1987) This level is so low that some supervisors complain about personnel falling asleep and difficulty in determining whether the facility is clean. The lower light levels also make it difficult to see paper copy properly (although relatively few personnel complained).

Nevertheless, The lighting measurements indicated that the overall screen contrast was measurably higher with lower ambient light levels, reinforcing the contention that seeing was more difficult with lights on. Also, poor placement of some light sources resulted in lamps being imaged on the VDT screen- reducing the contrast to virtually zero - or forcing operators to stare at a bright light when looking up from the console. The latter causes havoc with the operator's adaptation to the VDT screen.

The opposite problem appears in some analytical areas where people must read hard copy, sometimes printed with worn out ribbons. The light levels, approximately 230 lux (23 fc) are too low for this visual task. Current IES recommendations for offices with paper tasks range from 200 to 1000 lux, depending on the print quality with levels of 500 to 1000 lux. recommended for copy made with poor ribbons or pencil (IESNA, 1987). Lighting the analytical areas, however, is complicated by the alternating need to read both VDT's and hard copy. Raising the overall light levels may make it more difficult to read VDT screens unless luminaires are positioned properly and effective diffusers employed.

Other lighting problems concern the lamps and fixtures. Lamps are replaced seemingly at random so that cool white, daylight, and warm white bulbs appear on the same ceiling plane. The color temperature of these three bulbs are quite different; the effect of mixing lamp types is an unpleasant checkerboard appearance. Adding to the visual clutter, parabolic diffusers are used adjacent to eggcrate, prismatic diffusers and bare reflectors.

Recommendations:

* Lamp and fixture uniformity would improve the general office appearance and greatly simplify inventory requirements.

* In the operations and analysis areas, task lighting (a small lamp used to light the paper copy) might be useful, leaving the ambient lighting at a relatively low level. On the operations floor, another possibility is the use of supplementary up lighting to light the ceiling but not provide glare on the VDT screens. This would allow the overall levels to remain low, yet provide some visual interest to the space. Still another solution is greater use of parabolic fixtures to direct the light on the task while minimizing glare.

* The desks should be located so that there are no lamps directly in front of or directly behind the occupants if they are using VDT's.

4.1.5 Noise Issues

While environmental noise is not a major problem at either site, individual sources, primarily air handlers and printers sometimes produce unacceptable noise levels.

Another major noise problem was hinted at during the field measurement phase. Preliminary indications were that sound levels at the headsets are often above permissable OSHA limits for permanent hearing damage. Further research should document the levels that personnel actually listen to, and the period of this exposure.

Recommendations:

* Use printer covers to provide protection.

* Limit the number of personnel located near air handlers and other noisy equipment.

4.1.6 Shortages and Shortfalls

Conversations with the analysts, operators, and supervisors indicated major problems with furniture quality and durability (desks, chairs, cabinets, etc). Perhaps due to the 24-hour a day use, furniture is often broken - chairs have defective or missing arms, broken tilt mechanisms, desks have broken or missing drawers, missing locks, scratches, dents, etc. The atmosphere created is unpleasant, and sometimes (in the case of chairs) can be a potential hazard. Exposure to other areas in the facility with better furnishings increases the sense of frustration and second class citizenship.

Contributing to these problems is uncertainty - people know they are going to move - sometime. As a result, repairs are not made, equipment not refurbished, needed painting not done, carpets remain wrinkled and dirty, and maintenance and cleaning are not performed. Layouts and offices are not planned and

furniture not positioned effectively. The uncertainty increases the unpleasantness of the environment, while adding to personnel stress and unhappiness. Failure to perform needed maintenance and cleaning contributes to the drab overall atmosphere. Other problems include the lack of windows; the depressing tunnel; the dim and ineffective lighting; bland and dirty walls and furniture; colorless cement/cinderblock walls; moldy walls; rumpled, dirty carpets; and overcrowded rooms.

Recommendations:

* Much of the facility could stand painting. If accomplished, with a variety of colors, and murals, borders, or pictures, as in the new area, the overall atmosphere would be improved. The planned rehabilitation is a logical starting place for such modification.

* Ergonomic chairs such as those used by FAA controllers should be tested to determine whether they will overcome the severe deficiencies noted in the chairs presently used by the military personnel.

4.1.7 Equipment

A major problem identified with the equipment is the shortage of terminals in a number of analytical areas. This is thought to interfere with productivity, and requires further examination in phase 2. It also increases employee frustration since they believe they could perform their jobs better with improved tools. While moving terminals from operations to analysis eases the problem for analysts, it is only a stopgap measure. It does not allow sufficient flexibility for the possibility of breakdown or emergency.

4.1.8 Break Areas

There are two major problems with the current break areas: there are none for non-smokers; and the air quality in smoking areas is terrible. Non-smokers must break in place, walk the halls or work floors (creating noise), or go to the snack bar two floors above. Smokers sit in a converted latrine with other smokers breathing incredibly smoky air. For them, air cleaners in the smoking areas appear to be a partial solution.

Recommendations:

* Air cleaners should be placed in the break areas.

4.1.9 Other Issues

The tunnel itself creates a morale problem, partly because its ambience is depressing, and partly because it serves as a

reminder that one is going underground for at least 8 hours. Exhaust fumes only add to the problem by making it harder to breathe and by increasing the dirt. Cleaning the tunnel is a problem as well.

4.2 ENVIRONMENTAL MEASURES AT SITE 2

During the initial visit, preliminary environmental measures were taken to describe the physical conditions. Three types of measures were involved. lighting, noise, and general environment (temperature, relative humidity, and particle counts) on the operations floor, the analysis area, and the main administrative area.

4.2.1 Lighting Measures

Lighting measures were taken at several locations. The measures included: overall illuminance (light level) on a white paper task; overall luminance (brightness) from the white paper and from a dark area located on it; luminance of the desk and keyboard; luminance of the screen without text; luminance of text on the screen; luminance of the brightest area of lamp visible; and luminance of the darkest area of the ceiling. Contrast between task luminance and surround luminance was then calculated from the luminance measures.

A number of observations are possible concerning the effects of lighting on task contrast. Table 2 presents the lighting measurement data for 33 locations in operations, 5 locations in the administrative area, and 18 locations in the analytical areas. The findings are separated into 2 categories "dimly lit areas" (table 2a) and "brightly lit areas" (table 2b). As a limited experiment, the last 4 entries for operations in table 2a were taken with the room lights dimmed (normal), while the first four entries in table 2b were taken at the same four stations with all the room lights on. This procedure was employed to address concerns about the effects of room lighting on task visibility.

The data from the four locations indicate that turning on the overhead lights noticeably reduced the contrast on the VDT screen (see table 3). The mean calculated contrast between the screen and screen character for these locations (given in Table 3) dropped from 0.90 to 0.48. The data for screen luminance show that the screen was "brighter" relative to the character, going from a luminance ratio of 10:1 to about 2:1, making characters much harder to see. With the same lighting changes, contrast for the paper task was also reduced slightly for the higher lighting levels. Thus, increasing light levels (illuminance) reduced task contrast for both hard copy and VDT tasks at the four locations examined. The increase in overall illuminance, 54 to 215 lux (5 to 18 fc) - was sufficient to diminish screen contrasts at the

Table 2. Lighting Measurements at Site 2

Table 2A. Dimly Lit Areas

Army Operations

Area	Type	Illum. Lux	Luminance in CD/M2 White Paper	Black Task	VDT Screen	VDT Char	Lamp	Ceiling	Desk	Keybrd
1	B&W DBL	43.0	7.9	0.5	1.1	4.8	29.0	1.4	1.1	2.4
	RT				1.5	4.6				
2	B&W DBL	53.8	17.0	0.8	2.7	6.8	31.6	2.4	1.3	3.9
	RT				2.7	5.2				
3	G&B	107.6	25.9	1.8	0.4	1.6	4590.8	3.2	22.3	2.6
4	B&W DBL	53.8	14.7	1.7	1.0	1.4	73.7	1.0	4.5	1.7
	RT				1.0	3.3				
5	G&B	21.5	4.4	0.4	0.1	0.5	229.5	1.9	3.2	0.4
6	G&B	10.8	12.2	1.4	0.1	0.8	883.9	2.3	17.2	0.3
	MN	48.4	13.7	1.1	1.2	3.2	973.1	2.0	8.3	1.9
	SD	30.9	6.9	0.6	0.9	2.1	1645.0	0.7	8.3	1.3

Operations

Area	Type	Illum. LUX	Luminance in CD/M2 White Paper	Black Task	VDT Screen	VDT Char	Lamp	Ceiling	Desk	Keybrd
1	DESK	86.1	20.1	4.5			483.1	2.5	1.7	
2	G&B	64.6	6.9	0.3	0.3	3.8	1771.2	2.5	4.9	14.0
3	B&W DBL	21.5	5.4	0.8	1.1	16.1	75.4	1.0	1.1	1.7
	RT				1.5	4.5				
4	B&W DBL	53.8	7.8	0.8	0.2	2.6	3871.4	5.5	1.0	2.7
	RT				0.3	4.0				
5	B&W DBL	107.6	24.9	1.5	1.7	16.8	750.3	3.2	4.1	3.9
	RT				3.2	10.2				
	MN	66.7	13.0	1.5	0.8	7.9	1390.3	3.0	2.6	5.6
	SD	29.2	8.0	1.5	0.6	6.0	1361.1	1.5	1.6	4.9

Air Force Operations

Area	Type	Illum. LUX	Luminance in cd/m2 White Paper	Black Task	VDT Screen	VDT Char	Lamp	Ceiling	Desk	Keybrd
1	G&B	21.5	1.5	0.1	0.1	1.2	503.6	0.9	1.2	0.2
2	B&W DBL	10.8	1.9	0.2	0.2	10.4	239.8	1.1		0.2
	RT				0.2	5.3				
3	B&W DBL	16.1	1.0	0.2	0.3	1.1	1.1	0.8	0.1	0.4
	RT				0.3	1.9				
4	B&W	322.8	84.3	5.0	2.1	3.3	5276.0	25.4	5.5	11.5
5	DESK	161.4	49.7	3.6			3124.5	5.9	4.5	
6	IBM	193.7			2.3	7.2	3244.4	8.3		36.0
1	IBM COL	86.1	19.5	1.7	0.7	1.9	3032.0	5.2	4.4	
2	IBM COL				1.0	1.7	3326.6	5.3		17.2
3	IBM COL	16.1	2.1	0.3	0.2	1.7	15.3	0.9	1.2	2.4

Table 2. Continued

Air Force Operations Continued

		Illum.	Luminance in cd/m2							
			White	Black	VDT	VDT				
Area	Type	LUX	Paper	Task	Screen	Char	Lamp	Ceiling	Desk	Keybrd
4		37.7	3.6	0.5	0.2	1.2	2435.9	1.3	2.2	0.7
5	B&W DBL	16.1			0.5	2.9	257.0	2.3		2.4
	RT				0.3	9.0				
6	G&W	69.9	21.9	2.7	0.5	3.7	3076.5	6.6	3.1	8.9
	MN	86.6	20.6	1.6	0.6	3.7	2044.4	5.3	2.8	8.0
	SD	95.5	27.2	1.7	0.7	3.0	1683.4	6.6	1.8	10.8

Operations Without Room Lights

		Illum.	Luminance in cd/m2							
			White	Black	VDT	VDT				
Area	Type	LUX	Paper	Task	Screen	Char	Lamp	Ceiling	Desk	Keybrd
1	G&B	86.1	23.7	1.7	0.1	1.4	3186.2	.0	22.4	4.5
2	G&B	64.6	15.1	1.0	0.1	1.4	4649.1	3.7	12.3	2.4
3	G&B	53.8	7.3	0.5	0.1	0.8	2083.0	1.5	5.4	1.5
4	G&B	10.8	2.7	0.2	0.1	0.6	877.1	0.9	0.6	1.0
	MN	53.8	12.2	0.9	0.1	1.1	2698.8	1.5	10.2	2.3
	SD	27.4	8.0	0.6	.0	0.4	1391.0	1.4	8.2	1.3
	GMN DIM	68.9	15.89	1.34	0.76	4.04	1782.2	3.6	5.5	5.1
	GSD DIM	68.0	18.04	1.33	0.77	3.95	1679.1	4.7	6.5	7.8

Table 2B. More Brightly Lit Areas

Operations With Room Lights On

		Illum.	Luminance in cd/m2							
			White	Black	VDT	VDT				
Area	Type	LUX	Paper	Task	Screen	Char	Lamp	Ceiling	Desk	Keybrd
1	G&B	193.7	69.9	13.7	1.6	2.7	801.7	5.6	1.4	7.6
2	G&B	215.2	68.5	4.8	1.3	2.2	1853.5	4.4	64.8	6.6
3	G&B	150.6	37.3	5.8	1.0	2.3	4933.4	8.1	32.1	5.9
4	G&B	215.2	66.1	12.7	1.3	2.9	3597.3	8.3		9.5
	MN	193.7	60.5	9.2	1.3	2.5	2796.5	6.6	32.8	7.4
	SD	26.4	13.4	4.0	0.2	0.3	1587.2	1.6	25.9	1.4

Navy Operations

		Illum.	Luminance in cd/m2							
			White	Black	VDT	VDT				
Area	Type	LUX	Paper	Task	Screen	Char	Lamp	Ceiling	Desk	Keybrd
1	B&W	53.8	7.2	0.9	0.3	1.8	48.0	3.0	6.5	1.1
2	B&W	107.6	18.3	2.3	0.4	2.4	4248.2	3.3	12.0	1.4
3	B&W DBL	86.1	259.0	29.8	1.7	3.6				
	RT				11.3	13.1				

Table 2. Continued

Navy Operations Continued

Area	Type	LUX	White Paper	Black Task	VDT Screen	VDT Char	Lamp	Ceiling	Desk	Keybrd
4	DESK	322.8	53.1	5.8			5721.4	8.1	31.4	
5	B&W DBL	53.8	23.1	1.3	0.7	3.4	2703.1	3.3	0.3	3.8
	RT				0.7	0.0				
6	STATION	75.3	16.5	1.9			3426.0	24.7	3.8	
	MN	116.6	62.9	7.0	2.5	4.0	3229.3	7.8	24.3	2.6
	SD	94.1	88.9	10.3	3.9	4.2	1880.7	7.8	31.8	1.4

Administrative Area

Area	Type	Illum. LUX	Luminance in cd/m2 White Paper	Black Task	VDT Screen	VDT Char	Lamp	Ceiling	Desk	Keybrd
1	SEC DESK	365.8	86.7	15.8	6.9	39.4	4351.0	55.8	9.6	38.7
2	OFCR DESK	645.6	181.9	19.2			4864.9	31.9	25.4	
3	SEC DESK	247.5	70.2	6.5			4179.7	16.2	5.8	
4	G&B	624.1	179.2	19.5	8.0	20.3	6440.9	27.8	24.0	63.0
	W/CARDBD				3.7	18.1				
5	OFCR DESK	376.6	105.9	8.2			3837.1	61.7	6.9	
	MN	451.9	124.8	13.8	6.2	25.9	4734.7	38.7	14.3	50.9
	SD	156.2	46.9	5.5	1.8	9.6	915.3	17.3	8.5	12.2

Army Analytical Areas

Area	Type	Illum. LUX	Luminance in cd/m2 White Paper	Black Task	VDT Screen	VDT Char	Lamp	Ceiling	Desk	Keybrd
1	SUPV DESK	236.7	63.4	5.5			1880.9	22.1	4.8	
2	SUPV DESK	322.8	79.1	8.2	2.4	3.7	3563.0	23.4	31.2	35.6
3	DESK	322.8	89.8	7.9			1531.4	18.6		
4	IBM GRN	322.8	86.0	9.3	5.3	11.3	2100.1	23.9	8.6	36.0
5	IBM G&W	322.8	68.2	9.4	3.6	25.8	2569.5	21.3	7.3	37.7
6	IBM G&W	236.7	58.9	4.9	4.4	29.2	2829.9	17.8	44.2	31.5
7	DESK	269.0	99.4	8.6			2596.9	18.5	12.2	
8	IBM G&W	107.6	26.1	2.7	2.4	4.6	1151.1	9.3	0.7	21.0
9	USI G&W	247.5	68.2	6.2	3.7	51.4	1291.6	18.1	74.0	33.2
10	HALL DESK	129.1	29.7	3.9	2.2	18.1	2100.1	12.5	15.9	17.0
11	USI G&W	269.0	63.7	5.7	3.8	17.8	2189.2	25.7	50.0	28.1
12	HALL DESK	86.1	26.8	1.6			1480.0	9.1	23.5	
13	DESK	290.5	81.5	16.1			2322.8	20.3	58.6	
14	DESK	172.2	43.2	6.4			2288.6	9.6	4.7	
15	USI G&W	129.1	36.7	4.2	3.1	11.4	2271.4	10.6	3.6	15.5
16	DESK	408.9	104.8	11.3			3001.2	33.2	12.7	
17	DESK	215.2	53.8	0						
18	IBM G&W	107.6	20.3	2	1.3	5.4	5550.1	6.1	28.6	10.5
19	IBM COL	161.4	43.9	5.1	1.4	5.1	5344.6	6.8	3.1	25.8
	MN	229.4	60.18	6.27	3.05	16.70	2559.0	17.1	22.6	26.5
	STD	89.7	25.11	3.69	1.18	13.75	1179.0	7.3	21.4	8.9
	GMN	238.0	70.19	7.86	3.02	12.33	3033.4	5.07	22.6	20.7
	GSTD	139.0	51.05	6.30	2.60	12.94	1540.2	3.97	23.4	16.0

Table 3. Calculated Measures of Contrast and Contrast Ratios at Site 2

Area	Type	Illum LUX	Paper Tasks Contrast	Paper Tasks Contrast Ratio	VDT'S Contrast	VDT'S Contrast Ratio
1	B&W DBL	43.0	0.94	16.4	0.77	4.3
	RT				0.68	3.1
2	B&W DBL	53.8	0.95	21.6	0.60	2.5
	RT				0.48	1.9
3	G&B	107.6	0.93	14.2	0.74	3.9
4	B&W DBL	53.8	0.89	8.7	0.28	1.4
	RT				0.71	3.5
5	G&B	21.5	0.91	11.7	0.75	4.0
6	G&B	10.8	0.88	8.7	0.83	6.0
	MN	48.4	0.92	12.5	0.65	2.7
	SD	30.9	0.03	12.1	0.16	2.3

Operations

Area	Type	Illum LUX	Contrast	Contrast Ratio	Contrast	Contrast Ratio
1	DESK	86.1	0.78	4.5		
2	G&B	64.6	0.96	22.2	0.93	13.8
3	B&W DBL	21.5	0.86	7.1	0.93	14.7
	RT				0.67	3.0
4	B&W DBL	53.8	0.90	10.4	0.92	12.5
	RT				0.93	14.7
5	B&W DBL	107.6	0.94	16.9	0.90	10.0
	RT				0.69	3.2
	MN	66.7	0.89	8.4	0.85	9.5
	SD	29.2	0.06	5.3	0.11	9.9

Air Force Operations

Area	Type	Illum LUX	Contrast	Contrast Ratio	Contrast	Contrast Ratio
1	G&B	21.5	0.93	14.7	0.94	17.5
2	B&W DBL	10.8	0.13	9.2	0.98	43.6
	RT				0.95	22.0
3	B&W DBL	16.1	0.83	5.8	0.70	3.3
	RT				0.84	6.1
4	B&W	322.8	0.94	17.0	0.35	1.5
5	DESK	161.4	0.93	13.7		
6	IBM	193.7			0.68	3.2
1	IBM COL	86.1	0.91	11.4	0.62	2.6
2	IBM COL				0.41	1.7
3	IBM COL	16.1	0.85	6.7	0.88	8.2

Table 3 Cont. Air Force Operations Continued

		Paper Tasks		VDT'S	
4	37.7	0.86	7.1	0.86	7.2
5 B&W DBL	16.1			0.84	6.1
RT				0.97	29.2
6 G&W	69.9	0.87	8.0	0.86	7.2
MN	86.6	0.81	12.9	0.78	5.8
SD	95.5	0.24	16.0	0.19	4.4

Operations - Dimly Lit Areas

Area Type	Illum LUX	Contrast	Contrast Ratio	Contrast	Contrast Ratio
1 G&B	86.1	0.93	13.6	0.90	10.2
2 G&B	64.6	0.93	14.7	0.93	13.7
3 G&B	53.8	0.93	15.1	0.88	8.0
4 G&B	10.8	0.93	13.3	0.89	9.0
MN	53.8	0.93	14.1	0.90	10.3
SD	27.4	.00	13.5	0.02	14.5
GMN	68.9	0.87	11.9	0.78	5.3
GSD	68.0	0.16	13.6	0.18	5.1

More Brightly Lit Areas
Operations

Area Type	Illum LUX	Contrast	Contrast Ratio	Contrast	Contrast Ratio
1 G&B	193.7	0.80	5.1	0.41	1.7
2 G&B	215.2	0.93	14.4	0.40	1.7
3 G&B	150.6	0.84	6.4	0.56	2.3
4 G&B	215.2	0.81	5.2	0.55	2.2
MN	193.7	0.85	6.5	0.48	1.9
SD	26.4	0.05	3.4	0.08	1.5

NAVY OPERATIONS

Area Type	Illum LUX	Contrast	Contrast Ratio	Contrast	Contrast Ratio
1 B&W	53.8	0.88	8.4	0.81	5.3
2 B&W	107.6	0.87	8.0	0.85	6.5
3 B&W DBLE	86.1	0.88	8.7	0.52	2.1
RT				0.14	1.2
4 DESK	322.8	0.89	9.2		
5 B&W DBLE	53.8	0.94	17.8	0.79	4.8
RT					0.0
6 STATION	75.3	0.89	8.9		
MN	116.6	0.89	9.0	0.62	1.6
SD	94.1	0.02	8.6	0.27	1.1

Table 3 Cont. Administrative Areas

Area	Type	Illum LUX	Paper Tasks Contrast	Paper Tasks Contrast Ratio	VDT'S Contrast	VDT'S Contrast Ratio
1	SEC DESK	365.8	0.82	5.5	0.83	5.7
2	OFCR DESK	645.6	0.89	9.5		
3	SEC DESK	247.5	0.91	10.8		
4	G&B	624.1	0.89	9.2	0.61	2.5
	W/CARDBD				0.80	4.9
5	OFCR DESK	376.6	0.92	12.9		
	MN	451.9	0.89	9.0	0.74	4.2
	SD	156.2	0.04	8.6	0.10	5.2

Analytical Areas - Army

Area	Type	Illum LUX	Contrast	Contrast Ratio	Contrast	Contrast Ratio
1	SUPV DESK	236.7	0.91	11.6		
2	SUPV DESK	322.8	0.90	9.6	0.35	1.5
3	DESK	322.8	0.91	11.4		
4	IBM GRN	322.8	0.89	9.3	0.53	2.1
5	IBM G&W	322.8	0.86	7.2	0.86	7.2
6	IBM G&W	236.7	0.92	11.9	0.85	6.6
7	DESK	269.0	0.91	11.6		
8	IBM G&W	107.6	0.90	9.6	0.49	2.0
9	USI G&W	247.5	0.91	11.1	0.93	13.9
10	HALL DESK	129.1	0.87	7.5	0.88	8.1
11	USI G&W	269.0	0.91	11.1	0.79	4.7
12	HALL DESK	86.1	0.94	16.6		
13	DESK	290.5	0.80	5.1		
14	DESK	172.2	0.85	6.7		
15	USI G&W	129.1	0.89	8.7	0.73	3.7
16	DESK	408.9	0.89	9.3		
17	DESK	215.2	1			
18	IBM G&W	107.6	0.9	10.2	0.76	4.2
19	IBM COL	161.4	0.88	8.6	0.73	3.6
	MN	229.4	0.90	9.6	0.72	5.5
	STD	89.7	0.04	6.8	0.17	11.6
	GMN	238.0	0.89	8.9	0.66	4.1
	GSTD	139.0	0.04	8.1	0.20	5.0

four measuring stations. (The phase 2 work will provide much more comprehensive information on this issue.) In the administrative area, mean illuminance was much higher, 452 lux (42 fc). This is an area where paper tasks predominate and human interaction occurs regularly; use of VDT's is less frequent. Illuminance was lower, 229 lux (21.3 fc) in the analysis area, where a mix of paper and VDT tasks occur.

Mean luminance for paper tasks followed the pattern for overall illuminance - ranging from 4-6 cd/m^2 for different operations areas without overhead lights or task lighting, to about 18 cd/m^2 for areas with extra lighting (including the analytical areas). Mean luminances for paper tasks in the administrative area were about 36 cd/m^2. Mean screen luminances ranged from 0.1 to 1.2 cd/m^2 without room lighting and 1.3 to 6.2 cd/m^2 for more brightly lighted areas. For dimly lighted areas mean screen character luminances ranged from 1.1 to 7.9 cd/m^2, and 2.5 to 25.9 cd/m^2 for more brighter areas. Further measurements will be taken for the VDT screens with and without overhead (and task) lights in phase 2.

The luminances of the lamps varied widely depending on the visibility of the light bulb itself. Where the lamp was directly in the field of view, luminance was as high as 6440 cd/m^2. Where the lamp was shielded by diffusers, or offset from the direct field of view of the operator, luminance was as low as about 48 cd/m^2. Ceiling luminances ranged from a low of about 0.75 cd/m^2 to a high of about 55.8 cd/m^2. Mean lamp luminances were 1775 cd/m^2 for dim areas and 3193 cd/m^2 for bright areas, while mean ceiling luminances ranged from 2.95 cd/m^2 for dim areas to 17.5 cd/m^2 for bright areas.

Several analysts said they often worked with copy made with printer ribbons needing replacement. Inspection of such copy suggested the contrast between the pale grey type and the paper was very low. The 269 lux (25 fc) available for reading the copy did not appear to be adequate for the task and is below the IES recommendations of 500 to 1000 lux for such tasks. Phase 2 will include more such measurements for paper tasks of low, moderate and high contrasts.

4.2.1.1 Comparison of Lighting - Site 1 and Site 2

Inspection of tables 1, 2, and 3 reveals that at the operations area in the main building of Site 1, illuminance levels were higher than at comparable areas at Site 2. The mean illuminance was 138 lux (12.8 fc), as compared with 69 lux (6.4 fc). Calculated screen contrasts were also slightly higher at Site 1, 0.86 compared with 0.78 at Site 2. Yet, the mean lamp luminance was higher at Site 2. There it was 1782 cd/m^2 compared with 1003 cd/m^2 at Site 1. This difference suggests that at Site 1, the

diffusers were more effective in shielding the lamp from direct view, while allowing more illuminance to reach the task.

In the first analysis area at Site 1, mean illuminance was also higher - 338 vs 229 lux. Only one VDT was measured at this location, so only the paper task contrasts can be compared. These were quite similar. Mean lamp luminance was much lower than at Site 2 - 981 cd/m^2 versus 2559 cd/m^2, suggesting that the diffusers were more effective in shielding the lamp from direct view.

Contrast ratios were also calculated for the two sites. Inspection of these data (Tables 1 and 3) indicate that for VDT tasks at Site 2, 31% of the stations failed to meet the minimum 3:1 ratio, and another 33% failed to meet the preferred 7:1 ratio recommended by National Academy of Science (NAS) (1983) and American National Standards Institute (ANSI) (1986). Of the 9 workstations at Site 1, only 14% failed to meet the 7:1 goal. (In phase 2, the effects of other variables will be explored using a much increased sample size. Among the parameters to be explored are: the effects of variations in luminaire and diffuser type, and luminaire position with respect to workstation, on contrast and contrast ratios.)

4.2.1.2 <u>Background Information Concerning Lighting Needs for VDT Tasks.</u>

Contrast ratio is a measure of character visibility on a VDT screen or on paper. It compares the maximum luminance with the minimum luminance. The proposed ANSI standard (1986) and the NAS report on VDT's (1983) both recommend a minimum contrast ratio of 3:1 and a preferred ratio of 7:1.

Contrast is another generally accepted measure of task visibility. It relates the brightness of a task to its surround, based on the premise that maximum visibility occurs when a task is as dark as possible, and its surround as light as possible. For a VDT screen, the situation is reversed - the characters are typically light and the background dark. To estimate task visibility, contrast for the paper and black area was calculated, as was contrast for the screen and screen character, using the following formula:

$$\frac{L\ min - L\ max}{L\ min} = C$$

where L min = background luminance (Minimum luminance) and L max = task luminance (Maximum luminance).

Use of this formula means that calculated contrasts can vary from 0 to 1. (When contrast is calculated for a VDT screen, the background screen is treated as the task and the lettering is treated as the background, so contrasts can be compared.) Rea (1981) demonstrated that contrasts below 0.3 resulted in serious degradation of visual task performance.

Calculations of both contrasts and contrast ratios for workstations at sites 1 and 2 are given in Tables 1 and 3. These calculations provide a measure of the relative visibility of different types of tasks. They are subject to a number of cautions, however. First, the luminance of a very black area was employed as the paper task instead of standard printed text. This would enhance these contrast values. Secondly, luminance measurement of VDT screen characters often contained some amount of background screen. This could tend to lessen measured screen contrasts. Nonetheless, these measures indicate wide variation in both contrast and contrast ratio with noticeable reductions in contrast due to overhead illumination.

In a similar study, Shahnavaz (1982) measured illuminances and luminances for 28 VDT operators in a telephone information center. The operators were permitted to set lighting levels preferred for their task. Shahnavaz found that measured levels were well below values recommended by European researchers. His measured mean illuminance to be about 258 lux (24 fc) during day shift and 194 lux (18 fc) for the night shift - below the European recommended range of 215 to 753 lux (20-70 fc). Luminance of screen characters was 1.3 cd/m^2 at night and 2.4 cd/m^2 during days, while mean background luminance of the screen was 1.3-2 cd/m^2. The values are closer to the readings taken at Site 2 than are the European recommended levels, (although the contrast between screen and screen character was higher in the present study than in the cited investigation).

The data collected by Shahnavaz and the present study support the argument for lower illumination levels for VDT tasks, and, in fact, come closer to current North American recommendations. Values recommended by the IESNA for VDT - type screens range range from 200 to 1000 lux (20 to 100 fc) depending on the task; that copy from a worn out printer ribbon requiring more lighting.

It is interesting to note that reaction was more favorable to the lighting at Site 1 than Site 2. The use of generally low light levels, anti-reflective screens, different types of VDT screens and lighting fixtures, and possible better positioning of light sources relative to the task at Site 1 may have been responsible for this difference. In addition, mean calculated contrast for VDT screens tended to be higher at Site 1, further indicating a more effective lighting system.

4.3 ACOUSTIC MEASURES

The measured noise levels for operations are given in Table 4. The range for environmentally measured noise was from 64 dBA to about 80-81 dBA near printers and an air handler. Printers and conversations typically drove the noise level above the ambient 64-68 dBA on the operations floor. Ambient noise levels were similar for the analysis area, although analysts stated that measurements had been made at a quiet time. High sound levels (85-98 dBA) were recorded at several headsets. These measures were made with a microphone located at the outer edge of the headset, near the ear's customary position. These levels are high enough to damage the operators' hearing. In fact, many reported measurable hearing loss, but believed that the high noise levels were needed to perform their jobs. Further measurements will be taken during phase 2 to determine if these levels are typical.

Table 4. Noise Levels at Site 2

Operations Area

Environmental Noise Measurements

Location	Level in DBA
1	66 SUPV. DESK
2	81 PRINTER
3	66 GENERAL AREA
4	64 71W/PRINTER; 74 W/CONVERSTATION
5	80 AIR HANDLER
	71 PRINTER
	64 AMBIENT
6	70 W/CONVERSATION
	64-68 ARMY OPERATIONS GENERALLY

Preliminary Noise Measurements At Headphones

Location	Level in DBA
1	82
2	90-94 SEARCH
3	71
4	78 CLEAR SIGNAL
5	98 OP SET
6	74 OP SET
7	86 FAINT SIGNAL PRINTER 76-82
8	77 PRINTER 80-90
9	70
10	88 REPORTED HEARING LOSS
11	85 OLDER PERSON
12	70 YOUNGER PERSON
13	90 IN HEADSET -- REPORTED HEARING LOSS
14	85 IN HEADSET

4.4 THERMAL ENVIRONMENTAL MEASURES

The third set of measures involved temperature, relative humidity and particle counts. All were taken with a particle counter.

Mean temperatures tended to be low - between 66° F and 71° F with high relative humidities - 58% to 63%. The lowest temperatures were obtained during the evenings on the operations floor - 66° F with a relative humidity of 61-63%. These humidity levels are quite high relative to levels normally found in office buildings. They are as much as 2 to 2.5 times those measured at two office buildings in the Washington D.C. area. The mean relative humidity in an office at the National Bureau of Standards for a twelve hour period was 28.2% at a mean temperature of 73.6° F, for example. Meyer (1983) points out (p.27) that "extensive experimentation has shown that for an average, sedentary, lightly clothed person, this (thermal comfort) occurs most readily when the air in a standard room has a temperature of 24.5° C, a relative humidity of 40%, and an air velocity of 0.25 m/sec. According to thermal comfort standards currently valid in the US (ASHRAE standard 55-1981), "80% of all adults dressed for winter indoor conditions find temperatures acceptable between 68° F and 74.5° F (20-23.5° C), a relative humidity of 30-60%, and the air velocity at 0.15-0.25 m/sec. Acceptable summer indoor temperature is between 73 and 79° F (20-26.5° C)." Thus, the spaces at this site tend to be outside the ASHRAE comfort standards for both humidity and temperature for winter and summer conditions. Frequent complaints from personnel about the cold temperatures, particularly on the operations floor, reinforce this conclusion.

4.5 INDOOR AIR QUALITY

The third measure of indoor air quality was particle counts. The particle counter used counts the number of particles in six size ranges for pre-set time intervals. Particle size ranges include: 0.3-0.5 microns; 0.5-0.7 microns; 0.7-1 microns; 1-5 microns; 5-10 microns; and greater than 10 microns. This range covers respirable aerosol particles with oil and tobacco smoke being below 1 micron, atmospheric fine particles below 1 micron; and cotton and insecticide dust above 1 micron.

In terms of human health, Meyer (1983) notes that particulates between 1-100 millimicrons are retained in the nose and throat passages, particles between 0.01 and 10 are retained in the lungs and tracheobronchial passages, while particles smaller than 0.05 are often exhaled (unless they dissolve and react with surface tissues). While many particles are absorbed fairly rapidly in the body, others, such as asbestos, are retained in the pulmonary tissue and not passed out of the body.

Measurements of particle size were taken in three different locations - a vacant office in the Commanding Officer's (CO's) office (sampling interval of 15 minutes) from 2 pm to 9 am; at the supervisory area on the operations floor from 11 am to 3 pm (sampling interval of 10 minutes) and again from 3:30 pm to 9:42 am (sampling interval of 20 min); and toward the rear of the operations floor from 10:30 am to 2:30 am,(sampling intervals of 15 minutes). To facilitate comparing particle counts from different areas, the mean values at each location and sampling interval were standardized in cubic meters, while factoring out the sampling interval, according to the following formula:

Number of Particles/Sampling Interval x 0.0283

where 0.0283 is the conversion factor from ft^3 to $meter^3$. The converted values for the mean particle counts in each location are given in table 5. Summary statistics (means and standard deviations) are given for each size range for each location as well as for the whole site. Although the general size range of the particles at a limited number of locations at site 2 is known, it is difficult to compare these findings with other air quality data because until recently, sampling for particles was performed by weight rather than size.

Nevertheless inspection of Table 5 reveals that some marked changes occurred in particle distribution over time. The most marked change was in the CO's office area where the number of large particles (above 5 microns) dropped to zero at night when the office was vacant. Conversely, during the occupied hours, the number of very small particles (0.3 to 0.7) was often larger than the meter could report, going off scale several times between 13:57 and 16:37. Increases in the number of large particles which coincided with shift changes at 06:30, 14:30, and 22:30 were apparent on the operations floor. At the site labeled OPS1 (a supervisory area at the center of the floor), the number of particles of all sizes increased noticeably near shift change.

Inspection of table 5 reveals that more large particles (greater than 0.5) were found at OPS1 during the day - by a factor of almost 4 - while the concentration of small particles, below 1 micron, was greatest in the CO's office area. The relative increase in the CO's office was substantial compared to other sites. The reasons for this increase are not apparent, although the administrative area is served only through the central air conditioning, with no supplementary floor units. The operations floor, on the other hand, is served by both. Comparison of the particle counts with those taken in a private office at NBS indicated that the mean concentration of particles was very similar. Particle counts were generally slightly lower at Site 2 than at NBS for small particles, but somewhat higher for larger particles.

Table 5. Particle Concentration at Selected Locations

CO's Office - Sampling Interval = 15 minutes

LOCATION	TIME	VOL	VOL	VOL	VOL	VOL	VOL		%
Date	12/2	>10	5-10	1-5	0.7-1	0.5-0.7	0.3-0.5	TEMP	REL. HUM.
CO'S OFFICE									
=15	13:57	4.57E+02	2.41E+03	2.30E+06	9.04E+06	OFFSCALE	1.37E+06	70.8	61.2
	14:29	1.93E+02	1.24E+03	1.57E+06	8.79E+06	OFFSCALE	2.97E+06	70.8	61.2
	15:01	6.60E+01	8.34E+02	1.57E+06	9.00E+06	OFFSCALE	1.86E+06	70.8	60.8
	15:33	6.69E+02	2.18E+03	2.10E+06	9.85E+06	OFFSCALE	1.84E+05	70.8	60.4
	16:05	1.88E+02	1.22E+03	1.93E+06	9.61E+06	OFFSCALE	OFFSCALE	70.8	60.8
	16:37	1.04E+02	9.09E+02	1.82E+06	9.28E+06	OFFSCALE	OFFSCALE	70.8	60.0
	16:53	2.36E+02	1.51E+03	2.04E+06	9.28E+06	1.95E+07	1.36E+07	70.8	60.0
	17:25	1.60E+02	1.28E+03	1.75E+06	8.09E+06	1.80E+07	1.30E+07	70.8	59.6
	17:57	6.83E+01	4.52E+02	1.52E+06	7.75E+06	1.75E+07	1.25E+07	71.2	58.8
	18:29	7.07E+00	1.96E+02	1.43E+06	7.70E+06	1.75E+07	1.25E+07	70.8	59.6
	19:01	2.36E+00	7.07E+01	1.39E+06	7.66E+06	1.74E+07	1.22E+07	70.0	58.8
	19:33	0.00E+00	9.42E+00	1.47E+06	8.00E+06	1.75E+07	1.18E+07	70.8	58.8
	20:05	0.00E+00	4.71E+00	1.48E+06	8.08E+06	1.76E+07	1.17E+07	70.8	59.2
	20:37	0.00E+00	7.07E+00	1.47E+06	8.08E+06	1.77E+07	1.19E+07	70.8	58.4
	20:53	2.36E+00	2.36E+00	1.35E+06	7.75E+06	1.75E+07	1.22E+07	70.8	58.4
	21:25	0.00E+00	9.42E+00	1.23E+06	7.39E+06	1.73E+07	1.23E+07	70.4	58.0
	21:57	0.00E+00	4.71E+00	1.29E+06	7.56E+06	1.73E+07	1.20E+07	70.8	58.4
	22:29	0.00E+00	7.07E+00	1.26E+06	7.35E+06	1.70E+07	1.18E+07	70.8	58.4
	23:01	0.00E+00	2.36E+00	8.61E+05	5.48E+06	1.45E+07	1.54E+07	70.8	58.4
	23:33	0.00E+00	2.36E+00	5.27E+05	3.46E+06	1.07E+07	1.38E+07	70.8	58.0
	00:05	4.71E+00	7.07E+00	3.67E+05	2.17E+06	7.35E+06	1.13E+07	70.8	58.4
	00:37	0.00E+00	4.71E+00	2.97E+05	1.50E+06	5.12E+06	8.96E+06	70.4	58.4
	00:53	2.36E+00	0.00E+00	2.97E+05	1.38E+06	4.50E+06	8.15E+06	70.4	58.4
	01:25	0.00E+00	9.42E+00	2.67E+05	1.11E+06	3.55E+06	6.85E+06	70.4	58.0
	01:57	0.00E+00	1.18E+01	2.45E+05	9.52E+05	2.95E+06	5.90E+06	70.4	58.4
	02:29	0.00E+00	0.00E+00	2.41E+05	8.84E+05	2.66E+06	5.43E+06	70.4	58.4
	03:01	2.36E+00	4.71E+00	2.30E+05	8.39E+05	2.50E+06	5.15E+06	70.4	57.6
	03:33	0.00E+00	4.71E+00	2.15E+05	7.83E+05	2.33E+06	4.89E+06	70.4	58.0
	04:05	4.71E+00	1.18E+01	2.11E+05	7.60E+05	2.23E+06	4.67E+06	70.4	57.6
	04:37	0.00E+00	2.36E+00	2.12E+05	7.62E+05	2.23E+06	4.76E+06	70.4	57.6
	04:53	0.00E+00	2.36E+00	1.98E+05	7.18E+05	2.16E+06	4.69E+06	70.4	57.6
	05:25	2.36E+00	1.18E+01	1.93E+05	7.02E+05	2.12E+06	4.67E+06	70.4	57.6
	05:57	6.36E+01	1.74E+02	2.25E+05	7.22E+05	2.13E+06	4.62E+06	70.0	57.2
	06:29	9.42E+00	7.54E+01	2.30E+05	9.77E+05	4.78E+06	1.57E+07	70.0	57.6
	07:01	4.71E+00	4.00E+01	2.26E+05	1.01E+06	5.27E+06	1.64E+07	70.4	57.6
	07:33	2.36E+01	2.97E+02	3.05E+05	1.08E+06	5.18E+06	1.58E+07	70.0	58.0
	08:05	1.11E+02	7.28E+02	5.64E+05	3.01E+06	1.57E+07	0.00E+00	70.0	58.0
	08:37	6.12E+01	9.96E+02	6.67E+05	3.76E+06	1.80E+07	0.00E+00	70.4	58.8
	09:09	6.36E+02	2.27E+03	1.13E+06	5.91E+06	offscale	5.39E+06	70.4	59.2
	Mean	7.89E+01	4.36E+02	9.40E+05	4.83E+06	8.40E+06	8.11E+06	70.6	58.7
	St. Dev	1.61E+02	6.91E+02	6.77E+05	3.49E+06	7.37E+06	5.14E+06	0.3	1.1

Table 5. Continued

Operations - Sampling Interval = 10 min

OPS	TIME	VOL >10	VOL 5-10	VOL 1-5	VOL 0.7-1	VOL 0.5-0.7	VOL 0.3-0.5	TEMP	% REL. HU
S=10	11:01	3.51E+03	2.73E+03	3.00E+05	2.85E+05	9.29E+05	4.46E+06	70.0	58.4
	11:34	1.74E+03	1.29E+03	1.54E+05	2.02E+05	8.30E+05	4.43E+06	69.2	60.0
	11:56	2.15E+03	1.49E+03	1.85E+05	2.17E+05	8.23E+05	4.28E+06	69.2	60.0
	12:29	6.44E+03	3.12E+03	4.07E+05	3.44E+05	9.26E+05	4.09E+06	70.0	60.4
	13:02	1.81E+03	1.68E+03	1.32E+05	2.01E+05	8.59E+05	4.36E+06	69.6	60.8
	13:35	1.43E+03	1.03E+03	1.02E+05	1.77E+05	8.39E+05	4.65E+06	69.6	60.4
	13:57	1.14E+03	8.87E+02	1.41E+05	2.15E+05	9.08E+05	4.74E+06	69.6	60.4
	14:30	3.76E+03	2.72E+03	4.02E+05	3.96E+05	1.08E+06	4.78E+06	70.0	60.4
	15:03	2.17E+03	1.66E+03	2.57E+05	2.93E+05	9.44E+05	4.59E+06	69.6	60.8
	Mean	2.68E+03	1.84E+03	2.31E+05	2.59E+05	9.05E+05	4.49E+06	69.6	60.2
	St. Dev	1.57E+03	7.62E+02	1.10E+05	7.07E+04	7.68E+04	2.13E+05	0.3	0.7

Operations 1 - Sampling Interval = 20 min

OPS 1	TIME 12/2	VOL >10	VOL 5-10	VOL 1-5	VOL 0.7-1	VOL 0.5-0.7	VOL 0.3-0.5	TEMP	% REL. HUM
S=20	15:30	1.33E+03	1.36E+03	1.60E+05	2.54E+05	9.74E+05	4.70E+06	71.6	59.6
	15:51	1.17E+03	1.20E+03	1.38E+05	2.27E+05	9.14E+05	4.66E+06	71.6	58.8
	16:12	1.06E+03	1.27E+03	1.62E+05	2.92E+05	1.18E+06	5.82E+06	71.2	58.8
	16:33	1.31E+03	1.34E+03	1.41E+05	2.36E+05	9.54E+05	4.99E+06	71.6	58.4
	16:54	8.25E+02	1.00E+03	1.11E+05	1.82E+05	8.16E+05	4.53E+06	71.6	58.4
	17:15	8.36E+02	8.96E+02	9.22E+04	1.61E+05	7.20E+05	3.97E+06	71.6	58.4
	17:36	8.73E+02	9.93E+02	1.07E+05	1.74E+05	7.16E+05	3.75E+06	71.2	58.0
	17:57	9.79E+02	9.28E+02	1.01E+05	1.61E+05	6.39E+05	3.31E+06	71.6	58.0
	18:18	1.33E+03	1.28E+03	1.25E+05	1.86E+05	6.61E+05	3.06E+06	71.2	57.6
	18:39	4.88E+02	5.35E+02	8.06E+04	1.43E+05	5.67E+05	2.73E+06	71.2	57.6
	19:00	7.16E+02	7.35E+02	1.27E+05	1.74E+05	5.80E+05	2.54E+06	71.2	58.0
	19:21	1.30E+03	1.02E+03	1.08E+05	1.61E+05	5.45E+05	2.28E+06	71.2	58.0
	19:42	1.07E+03	1.07E+03	1.15E+05	1.65E+05	5.49E+05	2.19E+06	71.2	58.4
	20:03	1.27E+03	1.23E+03	1.27E+05	1.86E+05	5.84E+05	2.10E+06	71.6	58.0
	20:24	7.95E+02	6.75E+02	8.42E+04	1.46E+05	5.11E+05	1.92E+06	71.2	58.0
	20:45	1.89E+03	1.58E+03	1.34E+05	2.04E+05	6.29E+05	2.15E+06	71.2	58.4
	21:06	1.20E+03	1.09E+03	1.03E+05	1.63E+05	5.38E+05	1.89E+06	71.6	58.0
	21:27	1.70E+03	1.35E+03	1.28E+05	2.04E+05	6.37E+05	2.43E+06	71.6	58.4
	21:48	1.04E+03	1.13E+03	1.14E+05	1.90E+05	6.14E+05	2.31E+06	71.6	58.0
	22:09	1.17E+03	1.20E+03	1.08E+05	1.64E+05	5.21E+05	1.83E+06	71.6	58.4
	22:30	2.84E+03	2.34E+03	2.56E+05	2.82E+05	6.63E+05	1.85E+06	71.6	58.8
	22:51	1.93E+03	1.62E+03	2.62E+05	2.71E+05	6.23E+05	1.80E+06	71.6	58.4
	23:12	1.45E+03	1.12E+03	1.46E+05	2.30E+05	6.80E+05	2.13E+06	71.6	58.0
	23:33	1.72E+03	1.18E+03	1.10E+05	1.74E+05	5.40E+05	1.82E+06	72.0	58.4
	23:54	1.40E+03	1.01E+03	1.01E+05	1.70E+05	5.58E+05	1.89E+06	72.0	57.2
	00:15	1.20E+03	9.98E+02	1.07E+05	1.92E+05	6.47E+05	1.86E+06	72.4	61.2
	00:36	1.02E+03	8.00E+02	9.79E+04	1.79E+05	6.31E+05	2.00E+06	71.6	57.6
	00:57	2.18E+03	1.51E+03	1.23E+05	1.83E+05	6.11E+05	1.95E+06	72.4	58.0
	01:18	1.49E+03	9.45E+02	9.02E+04	1.71E+05	5.85E+05	1.85E+06	71.6	58.0
	01:39	8.09E+02	5.71E+02	8.03E+04	1.54E+05	5.47E+05	1.88E+06	71.6	58.0
	02:00	1.05E+03	9.59E+02	9.92E+04	1.68E+05	5.43E+05	1.79E+06	71.6	58.0
	02:21	1.06E+03	9.68E+02	8.52E+04	1.54E+05	5.15E+05	1.64E+06	71.6	58.0
	02:42	4.35E+02	3.59E+02	5.63E+04	1.27E+05	4.63E+05	1.52E+06	71.6	58.0
	3:03	1.06E+03	7.74E+02	7.67E+04	1.37E+05	4.58E+05	1.43E+06	71.6	58.4
	3:24	8.62E+02	7.17E+02	7.78E+04	1.43E+05	4.69E+05	1.51E+06	71.6	58.0

Table 5. Continued

Operations Continued

3:45	4.51E+02	3.96E+02	6.43E+04	1.44E+05	4.94E+05	1.57E+06	71.6	58.0
04:06	1.72E+03	1.09E+03	1.37E+05	2.75E+05	7.65E+05	1.92E+06	71.6	58.0
04:27	8.37E+02	6.71E+02	7.65E+04	1.54E+05	5.00E+05	1.49E+06	71.6	57.6
04:48	4.72E+02	4.06E+02	5.38E+04	1.36E+05	4.76E+05	1.58E+06	71.6	57.6
05:09	6.73E+02	5.28E+02	5.65E+04	1.26E+05	4.52E+05	1.47E+06	71.2	58.0
05:30	1.11E+03	7.88E+02	8.96E+04	1.62E+05	5.06E+05	1.56E+06	71.6	58.0
Mean	1.17E+03	1.02E+03	1.12E+05	1.83E+05	6.24E+05	2.43E+06	ERR	ERR
St.Dev	4.81E+02	3.75E+02	4.25E+04	4.25E+04	1.53E+05	1.10E+06	ERR	ERR

Operations 1 - Sampling Interval = 20 min

;=20		VOL	VOL	VOL	VOL	VOL	VOL		%
PS 1	12/2	>10	5-10	1-5	0.7-1	0.5-0.7	0.3-0.5	TEMP	REL. HUM.
;=20	05:51	8.89E+02	6.06E+02	8.73E+04	1.61E+05	5.15E+05	1.68E+06	71.6	58.4
	06:12	1.99E+03	1.50E+03	1.95E+05	2.41E+05	6.14E+05	1.91E+06	71.6	58.0
	06:33	3.72E+03	2.17E+03	3.12E+05	3.15E+05	6.63E+05	1.72E+06	72.0	58.8
	06:54	3.36E+03	1.93E+03	3.49E+05	3.82E+05	8.14E+05	2.22E+06	72.0	59.2
	07:15	1.91E+03	1.62E+03	2.50E+05	2.97E+05	7.01E+05	2.14E+06	71.6	58.8
	07:36	1.21E+03	1.11E+03	1.25E+05	1.94E+05	6.35E+05	2.49E+06	71.6	58.4
	07:57	9.82E+02	8.07E+02	1.04E+05	1.69E+05	6.31E+05	2.76E+06	71.6	58.0
	08:18	1.33E+03	8.48E+02	1.27E+05	1.91E+05	7.29E+05	3.34E+06	71.6	58.8
	08:39	8.36E+02	6.91E+02	1.09E+05	1.88E+05	7.69E+05	3.74E+06	71.6	58.4
	09:00	8.64E+02	8.23E+02	1.16E+05	1.98E+05	8.30E+05	4.08E+06	71.6	58.8
	09:21	9.73E+02	8.62E+02	1.10E+05	1.85E+05	8.47E+05	4.57E+06	71.2	58.0
	09:42	1.08E+03	8.73E+02	1.16E+05	1.89E+05	8.68E+05	4.82E+06	71.6	58.8
	AVG	1.27E+03	1.05E+03	1.25E+05	1.93E+05	6.45E+05	2.55E+06	71.6	58.3
	STD	6.43E+02	4.10E+02	5.96E+04	5.20E+04	1.49E+05	1.12E+06	0.3	0.6

Operations 2 - Sampling Interval = 15 min

LACE	TIME	VOL	VOL	VOL	VOL	VOL	VOL		%
	12/4	>10	5-10	1-5	0.7-1	0.5-0.7	0.3-0.5	TEMP	REL. HUM.
PS 2	10:29	1.66E+03	8.32E+02	8.21E+04	1.45E+05	6.22E+05	3.18E+06	67.6	60.8
	11:01	1.20E+03	4.71E+02	4.94E+04	1.12E+05	5.64E+05	3.09E+06	66.4	62.0
=15	11:33	5.37E+02	2.29E+02	3.15E+04	9.70E+04	5.73E+05	3.39E+06	64.0	64.0
	12:05	9.23E+02	4.24E+02	5.05E+04	1.09E+05	6.04E+05	3.60E+06	64.6	65.6
	12:37	6.62E+02	3.82E+02	4.00E+04	9.75E+04	5.65E+05	3.44E+06	65.2	62.8
	13:09	1.53E+03	7.80E+02	6.34E+04	1.19E+05	5.74E+05	3.27E+06	64.0	66.0
	13:25	1.47E+03	7.23E+02	6.38E+04	1.23E+05	6.10E+05	3.50E+06	66.4	63.6
	13:57	6.17E+02	3.58E+02	3.64E+04	1.03E+05	6.64E+05	4.62E+06	67.2	61.2
	14:29	9.87E+02	5.80E+02	5.19E+04	1.12E+05	6.43E+05	4.32E+06	67.2	61.6
	15:01	1.22E+03	7.02E+02	9.74E+04	1.75E+05	8.25E+05	4.88E+06	66.8	62.4
	15:33	6.76E+02	3.65E+02	5.01E+04	1.74E+05	1.04E+06	5.55E+06	67.2	62.8
	16:05	7.28E+02	4.10E+02	9.36E+04	4.78E+05	2.41E+06	7.82E+06	67.2	62.4
	16:37	1.77E+03	7.94E+02	5.79E+04	1.50E+05	9.36E+05	4.95E+06	66.8	62.4
	17:09	1.17E+03	6.38E+02	5.07E+04	1.25E+05	6.97E+05	3.96E+06	66.8	62.0
	17:25	1.48E+03	9.66E+02	6.11E+04	1.31E+05	6.78E+05	3.78E+06	66.8	62.0
	17:57	1.45E+03	6.27E+02	7.39E+04	1.71E+05	6.54E+05	3.20E+06	67.2	62.4
	18:29	9.28E+02	3.98E+02	4.08E+04	1.08E+05	5.24E+05	2.76E+06	66.8	62.8
	19:01	2.57E+02	1.58E+02	2.60E+04	8.41E+04	4.31E+05	2.27E+06	66.4	63.6
	19:33	1.08E+03	5.56E+02	6.24E+04	1.46E+05	5.25E+05	2.21E+06	66.4	64.0
	20:05	7.77E+02	4.22E+02	6.01E+04	2.42E+05	1.23E+06	4.27E+06	66.8	62.8

Table 5. Continued

Operations Continued

20:37	6.24E+02	2.83E+02	4.13E+04	1.25E+05	5.60E+05	2.40E+06	66.8	63.2
21:09	4.66E+02	2.52E+02	5.09E+04	3.52E+05	2.20E+06	5.16E+06	66.8	63.6
21:25	3.75E+02	2.10E+02	4.42E+04	5.77E+05	4.63E+06	1.04E+07	66.4	63.2
21:57	9.80E+02	5.14E+02	6.03E+04	1.77E+05	1.41E+06	4.93E+06	66.8	62.8
22:29	9.12E+02	5.11E+02	4.75E+04	1.31E+05	8.05E+05	3.22E+06	66.8	63.6
23:01	7.33E+02	7.68E+02	9.69E+04	1.83E+05	6.87E+05	2.57E+06	66.8	63.6
23:33	8.01E+02	4.99E+02	5.97E+04	1.25E+05	5.36E+05	2.52E+06	66.8	63.6
00:05	1.22E+03	6.29E+02	6.21E+04	1.32E+05	7.35E+05	4.67E+06	66.8	63.6
00:37	5.70E+02	4.22E+02	4.23E+04	1.14E+05	9.11E+05	6.84E+06	66.8	64.4
00:53	8.76E+02	4.90E+02	4.03E+04	9.89E+04	6.69E+05	5.38E+06	66.8	64.4
01:25	2.97E+02	2.83E+02	3.06E+04	9.34E+04	5.23E+05	3.62E+06	66.4	64.0
01:57	7.11E+02	4.83E+02	4.08E+04	1.11E+05	6.32E+05	3.80E+06	66.8	64.4
02:29	9.38E+02	5.51E+02	4.31E+04	1.14E+05	8.79E+05	5.95E+06	66.4	64.0
Mean	9.28E+02	5.06E+02	5.46E+04	1.62E+05	9.25E+05	4.23E+06	66.5	63.2
St. Dev	3.87E+02	1.94E+02	1.78E+04	1.06E+05	7.85E+05	1.69E+06	0.8	1.1

Summary Concentration Data

CO'S Office S=15 min	VOL >10	VOL 5-10	VOL 1-5	VOL 0.7-1	VOL 0.5-0.7	VOL 0.3-0.5	TEMP	% REL. HUM
Mean	7.89E+01	4.36E+02	9.40E+05	4.83E+06	8.40E+06	8.11E+06	70.6	58.7
St. Dev	1.61E+02	6.91E+02	6.77E+05	3.49E+06	7.37E+06	5.14E+06	0.3	1.1

Operations S=10 min	VOL >10	VOL 5-10	VOL 1-5	VOL 0.7-1	VOL 0.5-0.7	VOL 0.3-0.5	TEMP	% REL. HUM
Mean	2.68E+03	1.84E+03	2.31E+05	2.59E+05	9.05E+05	4.49E+06	69.6	60.2
St. Dev	1.57E+03	7.62E+02	1.10E+05	7.07E+04	7.68E+04	2.13E+05	0.3	0.7

Operations 1 S=20 min	VOL >10	VOL 5-10	VOL 1-5	VOL 0.7-1	VOL 0.5-0.7	VOL 0.3-0.5	TEMP	% REL. HUM.
Mean	1.17E+03	1.02E+03	1.12E+05	1.83E+05	6.24E+05	2.43E+06	71.6	58.2
St. Dev	4.81E+02	3.75E+02	4.25E+04	4.25E+04	1.53E+05	1.10E+06	0.3	0.6

Operations 1 S=20 min	VOL >10	VOL 5-10	VOL 1-5	VOL 0.7-1	VOL 0.5-0.7	VOL 0.3-0.5	TEMP	% REL. HUM.
Mean	1.27E+03	1.05E+03	1.25E+05	1.93E+05	6.45E+05	2.55E+06	71.6	58.3
St. Dev	6.43E+02	4.10E+02	5.96E+04	5.20E+04	1.49E+05	1.12E+06	0.3	0.6

Operations 2 S=15 min	VOL >10	VOL 5-10	VOL 1-5	VOL 0.7-1	VOL 0.5-0.7	VOL 0.3-0.5	TEMP	% REL. HUM.
Mean	9.28E+02	5.06E+02	5.46E+04	1.62E+05	9.25E+05	4.23E+06	66.5	63.2
St. Dev	3.87E+02	1.94E+02	1.78E+04	1.06E+05	7.85E+05	1.69E+06	0.8	1.1

4.5.1 Background Information on Indoor Air Quality

In terms of indoor air quality, the NAS (1981) identified a number of pollutants including the following: radioactivity, aldehydes, consumer products, asbestos and other fibers, combustion products (such as carbon monoxide, carbon dioxide, nitrogen dioxides, and particles), tobacco smoke contaminants (including particles, nicotine, carbon monoxide, chemicals (such as ozone, hydrocarbons, sulfur dioxide), particulates, allergens (such as fungi, algae, actinomycetes, arthropod fragments, dust, pollen), airborne microorganisms (such as bacteria and viruses). To this list, Meyer (1983) added contaminants such as water, skin scales, perspiration, and other human byproducts. Meyer (1983, p. 95) suggest "the worst problem in confined spaces is posed by particulates. Particulates will reach a level of 0.4 mg/m^3 after 100 hours in submarines. This is twice the level found in a smoggy day in Los Angeles". The effect of particulates depends on how deeply they penetrate into the respiratory system; those in the range of 0.5 to 5 millimicrons are the most dangerous because they are retained deep in the lungs. "Particles act synergistically with other pollutants because these small solids have enormous surface areas on which chemical reactions can be catalyzed by a variety of effects. Sulfur dioxide is an example of a substance with a greater toxic effect in the presence of sulfate particles, soot, coal dust, tobacco smoke and asbestos" (p.99). Still other problems are posed by tobacco smoke because carbon monoxide levels due to smoking can build up over 10 ppm (the EPA ambient 8 hour level) in indoor unventilated spaces (Meyer, 1983).

Although interior dust is so common and ubiquitous as to be unremarkable, it can carry microbes, allergens, radioactive particles, pesticides, pollens, molds, dust mites, insect and animal debris, human debris (such as skinscales), etc. Meyer noted that "the most common allergens are house dust, animal products, molds, bacteria, chemicals and pollen" (p. 256). Numerous reports have also pointed out that air conditioning and humidifying systems can be major sources of bacteria, virus, and molds or fungi (Meyer, 1983; NAS, 1981; Morris, 1986). These airborne biological contaminants are responsible for diseases transmitted through the air such as influenza, legionnaire's disease, smallpox, measles, pneumococcal pneumonia, rhinovirus, adenovirus, respiratory virus infections, and others. Morris (1986, p. 61) pointed out that "Respiratory infections are responsible for more lost time from work than any other causes, and it has been estimated by the federal government to cost over $100 billion per year in lost productivity and medical costs". NAS notes that "the incidence of respiratory conditions is just under one per person per year, and on an average, each person's activity is restricted for 4.5 days. If one grants that these illnesses are mostly due to indoor airborne contagion, the problem is seen to be enormous" (p. vii-86-87). The NAS further

indicates that allergens such as dust mites require temperatures of around 25° C and relative humidities of at least 45%, while damp walls may harbor different types of harmful fungi. Meyer notes that although "water is not normally considered a pollutant, moisture is an excellent solvent for many pollutants and thus influences their concentration; moreover, moisture acts as an important ingredient in the corrosive action of many pollutants (p. 165). Morris (1986) concludes that the air flow exchange rate has a direct impact on the concentration of viruses and bacteria.

With regard to Site 2, the above discussion has several important implications. First, the relative humidity levels can support bacteria and mold growth, which could result in lost time due to respiratory infections, illness, and allergic reactions. Secondly, the smoking areas might have excessively high levels of carbon monoxide since they are not on a separate air exchange system. Thirdly, the particle counts, although "in the same ballpark" as those for Washington, D.C. area buildings, pose potential dust problems, which could interact with the high humidity to allow airborne biological contamination.

5. CONCLUSIONS

At the two sites visited, a number of building and environmental design issues were identified as potential problem areas. In addition, a measurement protocol was developed for further detailed analysis of these areas.

One of the most important potential problems is that of lighting, particularly for areas where a mix of VDT and paper tasks occur. In many instances on the operations floor, the room illumination reduced contrasts on the VDT screens to unacceptably low levels. Yet, lowering the lighting levels to make more effective use of the VDT's resulted in a dim, gloomy appearance to the room, and made it more difficult to read paper copy. Coversely, in the analytical area, light levels were generally higher, but contrasts for VDT tasks also tended to be in the acceptable range. Here the problem was that of paper copy printed with poor quality ribbons. For this task, light levels were too low. Further research will concentrate on more detailed measurements of the interaction of VDT and paper tasks with different types of luminaires, lighting geometries, and light levels. The feasibility of solutions such as task lighting, uplighting, and specialized diffusers will also be explored.

Another problem area at both sites was that of unacceptable fluctuations in temperature and humidity. Site-wide air conditioning outages were common at the first site, while unacceptably cold temperatures and high humidities were common at the second site. Mold, mildew, and dust were also problems at the second site. In addition, smoking areas at this site clearly required a separate air-cleaning or exhaust system to deal with the build-up of smoke in the space. Further research will concentrate on a more complete characterization of the distribution of temperatures and humidities throughout the site.

While overall noise levels were not a particular health problem, individual noise sources such as printers and air handlers often created excessive noise. Greater use of printer covers would reduce the noise to more acceptable levels. Other noise problems involve distractions due to conversations in crowded areas. Here, the problem is the information content of the "noise". Yet, because many of the conversations are work-related, there is no easy solution. Still another potential noise problem is the level at which individual operators are listening in their headsets. Preliminary measures indicated that some levels were unacceptably high. Further research will concentrate on defining the general levels and duration of headset noise to determine if in fact a problem exists.

Other potential problem areas included space limitations, furniture condition and quality, maintenance, and general appearance, particularly at site 2. Because it is underground,

and does not have windows, personnel are cut off from the outside world. As a result, they may be more conscious of environmental defects. Nonetheless, in the analytical areas, severe crowding problems were identified, with individual analysts unable to backup from their desks in some cases without hitting someone behind them. Conversations and people movement were major distractions in the cramped rooms. Further research will concentrate on precise measurements of the space available, as well as on noise and lighting measurements for this area and the operations floor.

Furniture condition was a major issue also, with many chairs, desks, and cabinets in poor repair. One possible solution is to evaluate the effectiveness and durability of a set of ergonomic chairs, and inventory furniture conditions. The feasibility of modular furniture will also be explored as a potential solution in the next phase. Finally, developing and implementing a regularly scheduled maintenance program for the HVAC equipment, lighting systems, and general environment would be useful in increasing system durability and improving the functioning of the overall facility.

In the next phase of the research, detailed physical measurement and behavioral data will be collected to determine the impacts of lighting, temperature and air quality, noise, and the general environment on work performance. Such data are needed to determine the relative magnitude and extent of the potential problem areas identified above. During the initial phase measurement procedures and protocols were developed for this detailed evaluation. Based on the Phase 2 evaluation, a set of recommendations and design guidelines for improving the environmental quality will be developed for use in renovating existing facilities and designing new ones.

6. REFERENCES

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Appendices

A. Glossary
B. Protocol for Further Assessment of Site 2 and Other Field Stations
C. Edited Transcript of Interviews
D. Bibliographies
   (1) Stress
   (2) Shiftwork
   (3) Lighting

Appendix A. Glossary of Terms Used in the Text

The lighting definitions are taken from the IES Reference Handbook (1984).

Ambient Lighting - Lighting throughout an area that produces general illumination.

ANSI - American National Standards Institute

ASHRAE - American Society of Heating, Regrigerating, and Air Conditioning Engineers

Ballast - A device used with electric discharge lamp to obtain the necessary circuit conditions (voltage, current, and wave form) for starting and operating.

CFM - Cubic Feet Per Minute

Color Rendering Index - Measure of the degree of color shift objects undergo when illuminated by the light source as compared with the color of those same objects when illuminated by a reference source of comparable color temperature.

dBA - A logarithmic measure of sound pressure level, expressed as a ratio between two sound pressures, and weighted by the A weighting factor which adjusts the sound level measurements for variations in the response of the human ear to different frequencies.

Diffuser -A device to redirect or scatter the light from a source, primarily by the process of diffuse transmission.

Direct Glare - Glare resulting from high luminances or insufficiently shielded light sources in the field of view.

Disability Glare - Glare resulting in reduced visual performance and visibility. It is often accompanied by discomfort.

Discomfort Glare - Glare producing discomfort. It does not necessarily interfere with visual performance or visibility.

EPA - Environmental Protection Agency

FC - Footcandles

Glare - The sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance and visibility.

HVAC - Heating, ventilating and air conditioning system.

IESNA - Illuminating Engineering Society of North America

Illuminance - Density of the luminous flux incident on a surface; it is the quotient of the luminous flux by the area of the surface when the latter is uniformly illuminated. In lay terms illuminance is the amount of light falling on a surface. It is measured in Lux or foot candles. A foot candle = 10.76 lux.

INSCOM - U.S. Army Inteligence and Security Command

Louver - A series of baffles used to shield a source from view at certain angles or absorb unwanted light. The baffles usually are arranged in a geometric pattern.

Luminaire - A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and to connect the loops to the power supply.

Luminance - The quotient of the luminous flux at an element of the surface surrounding the point and propagated in directions defined by an elementary cone containing the given direction; by the product of the solid angle of the cone and the area of the orthogonal projection of the element of the surface on a plane perpendicular to the given direction. In lay terms, it is the amount of light reflected from a surface. It is measured in candelas/meter squared - (cd/m^2) or footlamberts. A footlambert = 3.426 cd/m^2.

Luminance Contrast; Contrast - Relationship between the luminance of an object and its immediate background. It is equal to $(L_1-L_2)/L_1$ where L_1 and L_2 are the luminaire of the background and object, respectively.

Luminance Ratio - Ratio between the luminances of any two areas in the visual field.

NAS - National Academy of Sciences

NBS - National Bureau of Standards

OSHA - Occupational Safety and Health Administration

Quality of Lighting - Pertains to the distribution of luminance in a visual environment. The term is used in a positive sense and implies that all luminances contribute favorably to visual performance, visual comfort, ease of seeing, safety and esthetics for the specific visual tasks involved.

Task Ambient Lighting - A combination of task lighting and ambient lighting within an area such that the general level of ambient lighting is lower than and complementary to the task lighting.

Task Lighting - Lighting directed to a specific surface or area that provides illumination for visual tasks.

TMJ - The Temporal Mandibular Joint is a socket on the lower jaw which can slip as a result of grinding or clenching teeth, causing neck aches, ear aches, or facial pain. It is often associated with stress or tension and results in a condition known as TMJ syndrome.

VDT - Video Display Terminals

Appendix B. Protocol for Further Assessment at Site 2 and other Field Stations.

B.1 Additional In-Depth Interviews
- a. Environmental specialist
- b. Information management specialist
- c. Group(s) of 4-7 operators
- d. Group(s) of 4-7 analysts
- e. Civilian support personnel (also military administrative personnel)
- f. Facilities personnel
- g. Administrative personnel

B.2 Additional Physical Measurements
- a. Lighting
  - (1) Illuminance on horizontal and vertical surfaces
  - (2) Luminance of white paper, black task, grey task, screen, screen character, lamp, ceiling
  - (3) Position of luminaire with respect to task
  - (4) Lighting contrasts in operational and analytical areas
- b. Noise levels in same areas including headphone measurements.
- c. Space and layout - detailed measurements of amounts of space available to analysts, operators, supervisors and support staff. Include desk size, room for moving chairs, number of file cabinets, number of tables, total size of space, total number of personnel/shift, overall cleanliness.
- d. Color of lamps, walls, desks, chairs, carpets, dividers.
- e. Lights - wattage, type, number, diffuser, task lamps (wattage, size, color), cleanliness.
- f. Air quality - radon, CO, temperature, humidity, air flow.

B.3 Questionnaire Administration

Administer questionnaire to selected staff picking at least 5-10 people from each operational area (such as Army, Navy, AF operations, Army, Navy, AF analysis, administrative people, computer support personnel, and headquarters) to determine the relative importance of different environmental factors to personnel at two or more field stations.

Appendix C Detailed interviews at Site 2

The following summarizes the views, comments, suggestions and reactions of people working at various jobs in selected areas at Site 2:

C.1. Army

C.1.1 Analytical Supervisory Personnel

In response to questions concerning environmental problems none were immediately identified at the outset of the interview. Personnel indicated that when a problem exists, it is readily attended to. The lighting is fine. There is some noise pollution; too many printers in a small area. No one's complained, but management is planning to order boxes to put around them. Space is a major issue. Over the last four months personnel has almost tripled, they are crowded in some areas. People are too close together, constantly bumping chairs, and must share computer terminals. There are about 34 terminals per branch, which operate on a 24 hour day schedule. As for chairs, they have plenty but have ordered some to upgrade their stock. Unlike operators, the analysts are mobile; they can walk around. When frustrated, they can go to a smoking area, or to the snack bar.

Analysts generally work individually, but sometimes must talk to each other to perform their jobs. They talk from their desks, or go to a colleagues desk and intrude into the other's activity (whether convenient or not). There is no place for conferring, so conversations sometimes cause problems for others. The mission takes precedence but this activity can be disturbing. When asked for a solution such as a small room. The response was yes, but.. better would be individual workstations, where everyone wears headsets and boom mikes. Depending on the task, one can signal not to be disturbed. If necessary, the do-not-disturb message could be overridden. People could exchange information and ideas on the screen and talk about it over the mikes. It would reduce walking around carrying paper. With respect to office design, the walls do not reach the ceiling - for proper air circulation. "We all listen to what's going on around us and then make decisions about whether to get involved even when not invited." If a conversation starts two desks away about a matter of interest, a person will attend to it, at the sacrifice of the task at hand. When sharing an office, one estimate was a 50% work degradation because of interruptions. Each person participates in a conversation, even when originally directed toward one individual. It is difficult to maintain a coherent train of logical, analytical thought. Work requiring great concentration is therefore often performed before or after regular hours.

Although it might appear to be desirable to distribute personnel evenly over the three shifts to reduce crowding and distractions contributed to by the open office design, (to minimize interruptions from people walking through, conversations, etc), the workload is heaviest on days. Supervisory personnel and the best workers are required then. As a result environmental needs must be balanced against supervisory control requirements. People must be available on days to resolve problems occurring during the preceding 24 hours. Some shiftwork assignments result in simple tasks taking 24 hours to complete. Passing information by notes from one shift to another is inefficient. The alternative is to work long hours. Because most questions get resolved in the daytime, more people are needed, so the office is crowded.

Dividers have been tried but were ineffective for reducing noise problems. Dividers helped only with an old Wang printer, which was so noisy that four dividers about 5' high were placed around it. One was hinged to serve as a door so the sound went straight to the ceiling or into the divider material. This printer was the biggest distraction; when something was printed, it affected everyone. It has since been replaced by another quieter printer (which has no sound shield, and so continues to be distracting).
Modular furniture was examined as a potential space saver to reduce the number of square feet required per person. At the field station space is tighter than at headquarters with only about 30 64sq. ft. per individual. When the aisles for movement are considered, space is very tight. Yet analytical jobs require thought and solitude and relative freedom from distractions. In some ways the operator's jobs are easier; they respond to a stimulus but don't have to analyze it. A particular problem occurs for the analysts at shift changes. An operator can fill in a replacement quite readily, but it is very difficult for an analyst to condense 8 hours of effort into 10 minutes.
Some interruptions are definitely attention-getters, e.g. where's the lost report? or the Army Times says "we're not going to be paid next month". These things can disrupt the entire office because everyone is so close. One must then sit down and recapture one's thoughts. Distractions make it difficult to integrate information. When trying to work on an idea, if someone bothers you, the idea could be gone forever.

One solution suggested was to make space available for conversations. Another was to employ headsets to allow the individual to determine whether to attend to information from the outside world. The headsets could be controlled to accept or reject input (unless a superior overrode the setting). A simpler solution is to have an area for each section, where material and work could be moved if quiet were needed. It could be set aside for work requiring concentration. It would have a terminal, and a place for laying out material if one had to move elsewhere temporarily. The volume of paper needed would not preclude this approach; much information is electronic.

As for other environmental impacts on the people; no sensory break is available after entering the tunnel. "There are no windows. Most buildings have places where it's easy to get outside. It's a quarter mile walk to the outside. Being under fluorescent lights all day with brick walls is annoying." Even after three years, without expecting it to be annoying, I feel the need to get outside at least once a day. If not, my family knows that I've not had a good day."

A major problem is the tunnel itself. It's the first thing seen in the morning and the last at night. "Whatever is done to the interior space, you're still faced with the drab and dreary tunnel." When asked about the feasibility of a break area above, the response was favorable; many people run the fields, often at lunch. A problem is the distance from tunnel to the fields. The tradeoff is a rapid office lunch. The analysts have more time for lunch. Their time is not monitored by computer as is the operators', where productivity is a major concern.
A nine-hour day is not feasible because there's no place for people to overlap. The operations people work an 8-hour day. Their time away from the desk is monitored, but they don't have to work overtime. The supervisory personnel work long hours and must overlap schedules to catch nuances of information.
With respect to terminal usage, some are networked, while others are individual. Often two to three analysts share a terminal, since policy is that a terminal must be used by at least two people. Yet because of intense terminal use, it is often desirable to have one terminal per person. The situation is most acute on days, when more people work, and deadlines come due. It's difficult to determine whether productivity is greater on mid and swing shifts, even with greater terminal availability, because the mix of work and personnel is different.
Lighting was not identified as a problem. (Ed note: I didn't either until I saw someone trying to read copy printed with a very bad ribbon under about 25 fc. It was very difficult to see the copy, and the person commented that this was a typical situation since ribbons get constant use and wear out quickly.)
With respect to temperature, it is often cold. The air distribution system is not efficient. There are far more complaints about cold than hot temperatures; most from the operations floor, where it's so cold that many people wear long underwear. The need for more fresh air and moving air was cited. Life in the facility was compared to a submarine, where people always feel better on the surface. More information is needed about the effects on people of working underground.
To a question about what could be done to improve conditions, one suggestion was that holographic walls might be helpful. The fluorescent skylight in the cafeteria feels "very outdoorsy" when one first arrives, but later, it's apparent "that sucker's got 40' of dirt on top of it". Curtains on walls would provide texture. Lowering overall noise levels would also be useful. One

can hear the printer even though it's supposed to be quiet. A cover would help but it would have to be bought or made, which is difficult to do. (Ed comment: At this point a video training tape started running in the background, which was very distracting.)

Training films are run during the day so troops can attend them. The only available viewing place is outside a supervisors office. They have lost classroom space so office space is used for instruction. They have also lost conference space due to staff increases. Losing the planned operational support facility outside has been a great blow. It meant that people on the second floor couldn't move, thereby cramping operations and analysis (particularly the latter) severely.

In terms of immediate "fixes", upgrading the break areas is needed since it's at least a 10 minute walk to the tunnel mouth. The current smoking area is a reconverted latrine which does not work as a break area for non-smokers. Concerning the terminals; the feeling was that many are terrible and need replacement. They are blurry and cheap, and the printers, slow and noisy. The primary need in the analysis area is to reduce noise distractions. White noise was suggested as a possibility. Now they have music, selected by the MP's at the gate and piped through the sound system. They have no control over the station selection or level.

The impact of sharing terminals is to reduce productivity. At times another person in a private office using the terminal (that's why he has two chairs behind his desk), yet when the door is closed, people can't get to this terminal. Sharing can lead to problems in meeting deadlines and ensuring that information is as recent and accurate as possible. Having physical training formations in the mornings also poses problems with the deadlines.

C.1.2 Army Analysts

An individual analyst was then questioned. When asked if noise were a problem, the response was that on days it was. He works straight swings (evenings with weekends off). It is particularly noisy from 0700 to 1400, being very distracting at times. As for lighting, he and two colleagues are located in a reconverted hallway where lighting poses some difficulty. One light is centered at the end of the hallway; one desk gets sufficient light, the second gets less, and the third very little. There is no planned relationship between the desk position and the lights. It is a temporary position which isn't too bad. The advantage of the lighting is they constantly view monitors and the subdued light reduces glare. Over an 8 hour day he spends about 6+ hours at the terminal. While monitoring the terminal, paper copy is used, and the job requires going back and forth between the two.

Most time is spent on the scopes. (Ed comment: The noise is very insistent.)

In response to a question about break areas, he commented it was more like "break in place" since neither he nor his colleagues smoke. With respect to temperature, it is comfortable, although cooler with fewer people at night and in the afternoon. By days it is back to normal. It is so cool that some (usually females, wear sweaters. He has always worn the uniform he has on (khakis). Everybody can choose the uniform to wear except on days with required formations. As for storage space, he has enough. Air quality is much improved since the smoking ban. Before that it was poor. At home his family would notice the smell of smoke and ask him to shower first. He doesn't notice much problem with mold or dust in the analyst area, although in other places one notices a musty smell when entering an office. He feels that generally the environment works well. (Ed :At this point, the place sort of shut down, with rock music coming over the PA accompanying the film on the danger of cocaine. It was also shift change time.)

C.1.3 Army Operations Supervisors

C.1.3.1 Lighting

Lighting is a major issue with the soldiers on the operations floor. It is difficult to determine whether their concerns and frustrations are real or not. They claim eyestrain is an issue. The supervisors preference is for more lighting because:
a)it's easier to keep the building clean
b)it keeps the soldiers more alert.

As soon as the lights are turned up, the soldiers complain and mention eyestrain.

What is the nature of their complaints? They claim that their eyes hurt, that there is glare. Operators spend 8 hours a day in front of the CRT listening to hard-to-decipher information. The burden is harder on them than on traditional VDT operators because of the need for intense concentration. The 8-hour day is interrupted by 3-10 minute scheduled breaks plus a 40-minute lunch break. At times operators must eat on position with food being brought in. Operators can't get up and leave when eyes are tired. (Ed note: Unlike the Army, the Navy provides task lighting on the desk so that operators could see paper tasks while still keeping the overall lighting levels low for the screens.) To an inquiry about the need for glasses, there was no awareness of changes over time. (Ed note: Conversations with troops on the operations floor suggested that some had recently gotten glasses, and some attributed it on work with the CRT's.)

C.1.3.2 Noise

Two sources of noise were identified on the operations floor:
a) Headsets: The soldiers listening through headsets to hard-to-hear stuff (he gave job series) are covered by the Army's hearing ability tests which require at least annual, if not more frequent testing of hearing. Hearing loss is an occupational hazard with this job classification. (Ed note: Conversations with individual operators revealed that many had measurable hearing loss.) With respect to headsets, they are large ones (like 10-year old Bose headsets); and not individually fitted, but standard issue to each operator. They are good sets which muffle outside noise. People have individual headsets which they carry in and out. Some keep them in the lockers.
b) Engineering generated noise through air handlers which depend on floor location. Several specific areas lead to complaints of headaches. One is being used as a break area. (Ed: the noise could defeat the idea of break area for rest and relaxation and taking deep breath. Noise is a stressor, so that if the area is very noisy, thereby negating the idea of a break.)
To a question about other noise issues, locations near the printers were mentioned.

C.1.3.3 Break Areas/Air Quality

The need for break areas is a major problem. There is no place for non-smokers. For smokers, several latrines were converted into smoking areas, but no such arrangement was made for non-smokers. The air quality in the smoking areas might be a health hazard. The army went to a rigid no-smoking policy which the CO has enforced, with smoking only in designated areas. Before, smoking was allowed on position. In a traditional building one can just walk outside and smoke. At the station, the walk to the outside takes 15-minutes, while the break is 10-minutes. The non-smokers use the area near the noisy air handler if they work nearby, but this used by only about seven people. The others don't have any place to go. Smoking is allowed only in the official break areas; people cannot smoke in the hallway.
In response to a question about what is needed in break areas: "Magazines, soft music, soda machines, and candy bar machine (so that troops don't have to walk all the way to the snack bar). Juke boxes or video games would not be appropriate. The Air Force brings in candy and has a table set up where troops can buy things. Army regulations would prohibit this. It is against the rules to have coffee funds or Christmas funds." The equipment is not user friendly because of its slow response. The speaker went into great detail about how the equipment works and what is wrong with it. Previous controls were analog, while now they are digital, requiring constant activation by tapping to make necessary adjustments.

C.1.3.4 Individual Army Operators

"People complain about the lights; many of them are out. There are frequent complaints of headaches. One problem is that the air handlers move air, while cooling; it gets very cold in midshifts. When it's cold upstairs, it's very cold down here. As you can see, I'm wearing a sweater." (Ed Comment: it was quite cool during our visit.)

The chairs are extremely uncomfortable particularly for 6-7 hours a day. The speaker wants more lower back support and feels the back of the chairs is too high. He feels that he doesn't need arms on his chair. "On some chairs you can adjust the back, but it's like lying backwards. The back is not firm enough. The chairs need to be height adjustable. Some people are 6-7 ft tall while others are shorter. Some want their feet to just touch the floor while others want their feet firmly on the ground, still others are in the middle." A footrest could be helpful, or maybe an ergonomic chair with the feet under the seat. The chair needs wheels to move on the carpet. Some are fine on linoleum, but won't slide on carpet. They must be durable; they receive 24 hours a day use.

As for headsets, he would prefer one that permits walking; such as a telephone extension cord. All it would take is a patch cord and a phone cord. (Ed comment: We may have seen something like this at Site 1.)

The speaker commented that shiftwork is a major problem. It takes 6 days to get adjusted, and then you are disrupted again. "It messes up your eating habits and your sleeping habits. The 6-2, 6-2 schedule isn't the best. A better scheme is to have a month of midshifts, and a month of swingshifts. There's got to be a better way." (Ed comment: When taking lighting measurements on the operations floor, 6-8 troops said that current shift schedules were very hard on them; they would prefer a longer time so their bodies can properly adjust.)

When chairs were mentioned the speaker responded there has been some improvement. But, many don't have arms. A good chair should be easy to adjust. Ambient noise is not a problem, because the headsets screen it out. He turns up the volume and gets lost in his work. The headsets are all right, although sometimes his ear becomes irritated because "the hard plastic is wearing out". Pads are used to cover up the worn area. He can hear quite a bit of background noise. The operators can determine when to concentrate and when not to.

The light bothers the speaker because of screen glare reflections. To a question about whether it is difficult to read papers in the low light, he said "no, not once you're used to the light level". He can readily go back and forth between the paper

and VDT. The paper serves as a reference to remind him of things.

The temperature can get quite cold particularly at night. If you want to wear a field jacket, you must be in regulation uniform. It is a problem going back and forth to outside (where it's much warmer). Clothing regulations prevent him from wearing a sweater or field jacket. As for space, no personal articles can be kept at the workstation. Smoking areas are a problem. When asked about desirable features for a break area, the following were cited:

* Separate area for non-smokers
* Soft cushioned chairs
* Vending machines for soda and candy
* Reading materials
* No piped-in music

Air quality is an issue. It is musty and moldy at the site. He has no problem with the temperature or with colds, and feels viruses will spread easily with so many people . As for the new barracks in A quad, "it's OK but not great. It has mold, and on weekends, they turn off the AC so it gets hot. The cafeteria has good food, but it is crowded."

The only thing that bothers him much about a windowless environment is the surprise about the weather when leaving. He would like the MP's to describe the weather every so often, particularly whether it's rainy or nice.

The speaker sees no real problem reading the VDT screens. He has been here since July, while another speaker has been there for 13 months. One speaker had been to Korea, which he preferred. He felt the equipment was better here but the work environment was better there. "They let you do your job with few regulations. It is more GI here. For example, there were visitors yesterday and we had to clean up for them; then somebody else was upset because we weren't doing our job." He feels pulled in conflicting directions.

With respect to the drab walls, there was little reaction. They get used to the environment and tolerate it. "It's like being a machine, you know you have to do it, so you do it". Several operators felt that the dark room is easier on the eyes and allows better control of screen contrast; better than the brightness adjustment on the screen itself. They use the brightness control sometimes. When asked about equipment needs, the only thing mentioned were headsets. In response to an inquiry about being "tied to" headsets; not being able to move around, one speaker commented on the desire to get up at least once an hour, stretch and walk around. He takes a smoke break, gets a

drink of water or walks around the bay. Everybody needed to do that.

Relationships with the analysts were then explored; do they talk to them much or have much social interaction? The speaker said he thinks they understand what analysts do, "we do our thing and they do their thing. It shouldn't really be like that; we should be working together but certain attitudes can't be overcome." When asked for suggestions, they indicated operators and analysts should get together and "dig out the information needed. New information would help with the task. Many case folders are outdated but nothing is done to make information more current." Specific tasks should be the topic of conversation between operators and analysts. The lack of such information makes it "almost impossible to do the job because they lose contact when a change occurs." The analyst may also lose continuity because the operator doesn't understand requirements sufficiently. (Ed comment: That doesn't seem surprising in view of the universal complaints about interruptions, noise, and space limitations from every analyst interviewed.)

Lighting is a real problem. "When the light here is turned on, the glare comes directly on the screen. The alternative is that a light comes directly on your eyes." The lights are too bright, and in the wrong direction. "Most of the lights have little squares, like those there. They break down the glare a lot." (Ed: The speaker referred to diffusers.) "Because the CRT is back lit, even if it were pitch dark, you can still see. The location of the lights is also a problem".

The temperature fluctuates and is often very cold. It is seldom comfortable. The noise comes and goes. As they add more equipment, you expect more noise. The noise doesn't have any effect on the job unless it's very loud and constant. The speaker has been here for three years and is an experienced operator. When asked if it bothered him to work underground, it did, sometimes especially coming up and down the tunnel bothers him. "If they would keep trucks out of the tunnel that would be great. Sometimes when you walk out the smell is worse than LA. As far as the tunnel itself (the facility) underground, it's a bummer. Stopping smoking has helped the air." The lack of a separate break area wasn't a problem because he prefers to break on position. It allows him to finish up work. Shift work is a problem. You've got to reverse your clock. A lot of people can't handle it, but he's been doing it for so long (3 years) that it is OK. Still, it takes a lot out of him and he's tired a lot.

C.2 Navy

C.2.1 Operations Supervisors

Space is a complex issue; they don't use what they have very well and yet need more. Because they have old equipment in a side-by-side configuration, they lose space. It would be more efficient to stack the equipment vertically. There is a desire to get rid of old printers, which take up too much space. Present technology is to use stackable components, occupying less floor space. Nonetheless, given the current mission load (which increases daily), operator space is not a real issue. Operators feel they don't have enough space, but this is disputed. (Ed comment: operators have more space than in Site 1.)

C.2.2 Analysts

A speaker commented on the temporary nature of the facilities, noting the frequent changes. He knows he's going to move across the hall sometime, but doesn't know when. He's been in his present office for four years, but a move was always imminent. He can't set up permanently; e.g. put charts and maps on the walls. Any addons are not taken seriously. They need new equipment such as desks and safes etc. Another speaker commented that they desperately need new carpeting, but nothing is done because of the "impending" move. There is no date for this move. With respect to the carpet, "the appearance is crummy". The floor has no carpeting in one area; "holes in the walls, holes in the ceiling it's horrible". Other comments were that it's too crowded, no privacy, too much movement and not enough space. For example people can't back up from their desk without bumping into someone.

The major problems are noise and crowded conditions, for people doing "brainwork". Too many telephones and terminals and equipment are in the space. There are lots of auditory distractions and people moving about and no privacy.
In response to a question about what temporary improvements might help, they mentioned a plan to free space, which might help some. The aesthetics of the space should be improved. Spreading out desks would help; they take up so much room. Smaller desks would not help; everyone requires one of the current size. The female in charge countered that watchstanders deal with great volumes of paper which must be spread out. More space would enhance efficiency.

In terms of files and stored items, certain things must be accessed regularly, but intermittently. Thus, material needed by one person is often stored on the edge of someone else's desk, because it's the only place available. For example they have stored a huge printer between two desks which cramps the space (nothing was said about noise from it.) Computers are not supposed to be on top of safes but there's no other place for them. "If we have one single problem, it is space. It is so cramped and so crowded."

When asked what would be the characteristics of a more desirable space, other than greater size; the response was more storage room. The furniture provoked strong reactions. It is second hand, hand-me-down. Most people have desks that don't lock, they have missing drawers or drawers that don't work. "It is just terrible to ask people to work under conditions like this. The general appearance is so awful, but there's nothing that we can do about it. The whole area is dirty. No amount of cleaning will change that. It's just really depressing to walk in here and look at the place and know you have to stay there for 8 hours."

As for changes recommended; painting, new carpet, and new chairs that worked. Perhaps more chairs like the one she has (one of the newer ones). People seem to like hers. Some people prefer chairs with a straight back while others don't. Some sit on chairs without wheels. In terms of desirable attributes for a chair, the speaker observed that personal preferences differ. Another speaker commented that some should have arms while others would not. Most important is that they be in good condition. Some adjustable chairs are needed. One person commented that he has a back problem, and is fussy about chairs. A common perception is that the number of square feet per person is low. People in this space are increasingly compacted since the move across the hall was canceled. "There are operating spaces in the building where you walk through and see oceans of space with few bodies working in them." Yet in their space, the bodies continue to squeeze together. The respondent suggested a comparative study of average square feet of floor space/person to see if space can be more evenly distributed. "On the second floor, there are offices with fewer people like 5-6 in a space the size of this one. We can see a great big empty room across the hall; that room is empty, yet they won't let us move until something else happens.

One speaker commented on the shortage of computers. When asked how that affects them, the response was "very much so". Six people are constantly fighting for one terminal. They can't do a good job. As a result much time is wasted. They can't access files when required. As mission priorities change, people bump people for time. Another speaker commented that to support analytical work, more terminals are needed. There are periods when some analysts just cannot function. As a result, two computers are being moved from the operational to the analysis area to alleviate the problems. This will cut the operations capability from 5 to 3 terminals and severely restrict emergency back-up of operational functions. The impact of too few terminals in the analytical areas is not information loss, but long-term analysis and support work is delayed. They have to wait in line for a terminal, resulting in inefficient man hour use. Time is spent waiting, rather than doing analysis. It is hoped that moving the terminals from operations will not create problems. If an emergency arises, it has the potential of a possible loss of

information, particularly if one or more of the remaining terminals go down.

When asked about the feasibility having one terminal per person, they thought a more reasonable solution is for a 50% increase in terminals. The benefits of an increase from 16 to 24 terminals is more efficient use of man hours; more work could be done; and the backlog would be removed. "It is very frustrating to stand in line to do something that needs doing. Eliminating that frustration, may well increase work output. Work often gets sloughed aside when no terminal is available. Also, more in-depth work such as writing would be completed. Doing a lengthy writing task severely ties up terminals which means it usually isn't done."

In response to a question about training areas, the speaker noted that they use "that desk over there with a big white board over it" (his desk) for training. He has to go to the library to get a VCR. People have to find VCR's from the library or training office. There is no place in the immediate area to listen to the VCR. (Ed comment: It clearly an approach which differs from the Army analysis area where training is in the same space and creates noise.)

When questioned about break areas, they commented unfavorably about the smoking areas, with one person saying that smokers were put in a hole together "until they die", another described it as an "antiseptic butt hole". When asked what characteristics a break area should have, they cited the need to separate smokers and non-smokers into two areas. "It should have soda and snack machines and something on the wall other than concrete and tiles to carry on a conversation because you can't talk in the current smoking areas. It needs something more pleasing to the eye such as murals, paintings or graphics on the bulkheads, subdued lighting, one or two plants, and magazines definitely."
When questioned about lighting, the desirability of glare screens was mentioned. They were ordered over a year ago but still haven't come. The following comment summarized the reaction of several people "why are we always on the bottom of the totem pole?" People are suffering from eye problems and severe headaches attributed to the lack of glare screens, which they have had difficulty getting. The set up is the standard workstation with a USI monitor. A potential glare problem was cited, since every light was on in the area. A great deal of paper work is performed, much in pencil, requiring all the lights. They expressed interest in the fixtures in the new space (parabolic fixtures). Dimmer switches were also requested. Excess sound causes difficulty in conversing. (ED comment:the complaints about noise were different from those expressed in the Army analytical area.)

Air quality is a major problem. People "coming on board" often get sick within the first week; headaches, head colds and chest colds are common. The sickness seems to be continuous and appears to have a cumulative effect. Odors are less of a problem since the smoking ban. Diesel fumes from trucks are apparent in the tunnel. The temperature is OK where they are, although it varies. It is cold on the operations floor in the evenings and it is often very humid in the building.

With regard to the tunnel: "The tunnel should have murals or photographs; perhaps historical information. There are military artists in each of the services. They could each do something about their services, ships, tanks, whatever they wanted, Semper Fi. Perhaps they could have a contest to fix up the tunnel. It is very depressing in the tunnel; a long walk, and an ugly one." To a question about windowless environments, one response was that after experiencing it for a long time, it is no longer annoying; others however, do get a claustrophobic reaction. Another speaker expressed a desire for a scene of sky and trees; similar to that in the cafeteria. The space for decorations such as nature screens is limited in operations because of the need to display information and training materials. Decorations could be a hazard in certain areas. Curtains could be used as sound absorbers and provide variety. Perhaps they could put up designs, cartoons or still lifes to enliven the space.
In mentioning the new 9000 sq ft facility, the comment was made that "people upstairs got new furniture, new safes, new carpeting, etc., when moving in, while we're left with all the old junk. The furniture is literally junk. It comes from junk yards all over the island. The situation becomes very, very depressing, and very hard to live with."

The conversation then turned to the trucks in the tunnel which belch diesel smoke. The speaker noted that the MP's strictly enforce no smoking in the tunnel while walking through, yet allow trucks and contractors to sit with large trucks and vehicles idling at the inner end of the tunnel. One day the fumes "got so bad in this very office that I could not see the end of the room from the desk."

C.3 Air Force Supervisor

The speaker has been at the field station for about 6 months. He was bemused by a recent article discussing the detriments of working shiftwork from a physiological and psychological point of view and mentioning the health hazards of 24 hour shiftwork, which he believes affects the troops adversely. He noted they talked about this 20 years ago when he worked shifts. Metabolism is thrown off by shiftwork. When you do it for 365 days a year, it has an impact on the body. He has seen nothing positive about 24 hour shift work. He pointed out that civilians working shifts get a pay differential after a given evening hour. Yet, in the

military it is the norm to work these hours. He pointed out that years ago they only had one headset per position. He suffered a severe ear irritation using a headset shared by another soldier, and had to ensure that the sets didn't touch his face. Now, each individual has a personal headset which can be modified as needed; this suggests that changes can occur. He believes that something might eventually be done to alleviate the problems associated with shiftwork.

He commented that a female operator kept getting headaches. It turned out that she had TMJ (Temporal Mandibular Joint), which was causing them. He observed that some operators go to the "shrink" because of stomach aches and pains and headaches. They can't cope with the work and have psychosomatic reactions. Sometimes this is associated with walking through the tunnel, coming into a dark room with no windows and sitting there for 8 hours a day on position. Others get nausea, and dizziness, attributed to the job. He thinks some of these symptoms are attributable to TMJ. Perhaps a screening profile could be developed for operators; to detect things like TMJ and potentially serious psychosomatic reactions. Then operators could receive attention for their medical problems as required.

With respect to noise; a humming from the AC on the operations floor was cited, also equipment with whirring fans. It is quieter on the operations floor as a result of equipment modification over the years. When asked about background music, the speaker answered that there is none in the Air Force or Navy area. As for human engineering, there is room for improvement, and the younger operators should be surveyed for their creative ideas.

As for space in the analytical area; people are back to-back with no spare room. Space is a critical issue. More people are crowded into less space. His commanding officer suggested that spacesaver desks might be useful; there is a need to think vertically rather than horizontally. Using workstations might well be a better way of using space. They need typewriters, desks, and disk packs but some materials can be stored over the desk.

A major shiftwork issue is that of meals. Troops are on midshifts from 10:30 pm to 6:30 am and typically they go to bed after a normal day's work. The midnight meal should be a breakfast meal (with eggs, bacon, fruit, and all that) rather than a full dinner with starches and meat. If the operators ate that, they could go home and go to bed at 6:30. (He noted that troops don't operate that way. They eat potatoes at 10:30 and then at 6:30 want to eat again.)

The conversation then turned to vacuum cleaners. The field station had gone hi-tech as much as possible. It is a

computerized area where dust is a problem because of equipment sensitivity . "So, what do they do? They buy commercial vacuum cleaners that sound like a deuce and a half truck and don't do the job. They break frequently." It might be due to frustration. To use one vacuum cleaner you had to be 6' tall. If you were any shorter, you couldn't use it because the handle was too long and had to be held at a weird angle.

As for chairs, he's had no feedback about them, but he is aware that it can get uncomfortable to sit at a terminal or station for 8 hours. Operators are given numerous chances to get away from their workstations. They have meal times, break details, and operator relief (OR) - they can sign off their machine for OR and go to the bathroom or to the smoking area. There are allowed periods (5-15 minutes) to log off and indicate they've gone on OR.. While this cannot happen at will, (the aisle controller must ensure that coverage is maintained) sometimes the supervisor will fill in, rather than sign OR (particularly for a short break). With respect to lighting, studies have shown that productivity increases when anything is done to the lights. (Ed: The Hawthorne Studies) On the operations floor lighting is subdued, and sometimes dark. This is for operator comfort while working with CRT's. Although the intensity of the screen image is changed, lights reflect on the screen obscuring the characters. He suggests examining CRT positions and see if paper has been placed behind and/or above to cut down glare.

The speaker suggested dividing the operations floor into people who are mobile (like analysts), not tied to head-sets, and those non-mobile, and compare reactions. While not all analysts are mobile (he came up with an example of an analyst who is "tied to a position"), the majority are. Most are "floor walkers" whose job is to deal with problems.

C.4 Facilities Personnel

C.4.1 Army Facilities Engineer

The engineer discussed the planned HVAC upgrade which was estimated to cost $9 million overall. All individual air handler units would be replaced with eight large high capacity units, and a chilled water loop. The HVAC is now provided by means of a mass of ducts which require repair and modernization. The air should be preconditioned before being brought inside. Now raw air is dumped directly onto the floor, and then conditioned. Preconditioning is more efficient,; it's less moist and cleaner. Final conditioning should be done later.

To a question about the ducts, he commented that they are often messy, but not a major problem. The coils in the unit need cleaning. The basic system is 40 years old but some parts are newer, 3-5 years old. The variable air volume system planned as

part of the upgrade is too expensive but the system still needs to be redone. The facility never had to shut down due to HVAC failure. There is a problem since air handlers are in the ceiling and floor. An upgrade would facilitate repairs and maintenance. The HVAC and plant power need improvement.
The quality of public power is very poor. The line must be conditioned for spikes. Backup generators take time to stabilize. Any power interruption causes major equipment problems. A comprehensive system design is required for the new AC system. When asked about raised floors, he responded that the raised floor, dropped ceiling technology allows flexibility for utilities.

The loss of the planned 50,000 sq ft outside facility creates space problems and affects the timing of the planned rehabilitation. The sequence of events had to be choreographed carefully, and depended on moving some administrative functions outside. Thus, the change in timing of the utilities upgrade has created a domino effect; all the synchrony is gone. The second floor rehabilitation is now in jeopardy. Although trailers might seem to be a solution to the space problems, temporaries have a way of becoming permanent.

Another critical problem in any rehabilitation scheme is to standardize equipment to ease the problem of different sized replacement parts and filters. This would ease both a stocking and reordering problem. The facility is a maintenance nightmare. It is very difficult to maintain an inventory. There are two different types of raised flooring. The ceiling tile vary in size, so that when repairs are needed, tiles often have to be cut to fit. The place has grown like topsy. As for relamping, there is no scheduled program. If a lamp burns out, people go to the shop for the part and replace it themselves. People on the floor turn off the lamps intentionally. Relamping is done very casually, with lots of minor things done by users. There is little help. As a result, much is left undone. Being a member of the Engineering Corps is an asset; it enabled him to get the parking lot graveled, for example.

A major problem is getting maintenance and repairs done, since everyone doing it must be cleared. That was a major problem in planning for the HVAC upgrade and a significant contributor to the overall expense. Another problem is the difficulty making changes in an existing operational facility. Mantech has an HVAC mechanic and an electrical engineer. They also supply a site manager.

C.4.2 Additional Site Management Personnel

One speaker began by commenting on the asbestos results from a consulting engineering firm concerning the proposed renovation. "They measured asbestos levels on all three floors, although they

concentrated on old storage rooms. They found asbestos on August 22, 1985. They cleaned it out in this area. The Corps of Engineers cleaned it up again by putting up wood frames with hard plastic and did the cleanup inside. They found asbestos in two other areas, the repair and utility shop ceiling and the transformer vault. In these areas they sealed the asbestos. As long as the surface seal is not broken, the asbestos is inert. Removing asbestos in these areas was part of the HVAC upgrade, but they won't tackle it now until another contract or the need to break apart walls. Asbestos is also on the hot water boilers storage tank in the HVAC plant. That has been treated and coated, not removed. When anybody works in the facility, the contractor must have a license to remove asbestos, and the work is later reviewed."

He monitors all ceiling work, whether putting in a nail, putting up a board, electrical, or conduit work. Consulting engineers are brought in when tests are needed. He knows that very small levels of asbestos affects humans and once asbestos is touched, it begins to deteriorate. "In a building like this, it can enter the ventilation system, particularly if someone tampers with an open duct. If some did get inside, it would be hard to track down. Everything would have to be ripped up and cleaned out." His procedure is to keep close touch with work in the ceiling areas. He worries about it, because so many changes and additions are being made. A pipe could be ripped out of the wall or a hanger from the ceiling, disturbing the asbestos.

He had an environmental test performed in association with the consulting engineering firm in 1983. His primary concern was a boiler inside the power plant putting out 100% carbon monoxide. They had a 200' flue with no vertical rise (a rise is required every 25'). Additional work was needed so he contacted the Army Environmental Health Agency. They visited in August 1985 and looked at the chemicals in the stack including nitrous oxide (NOX) from the diesels. There were many respiratory complaints from the electronic maintenance area on the third floor. The Army group looked for NOX and aldehydes. They didn't find much (except for the above-mentioned flue.) The purpose of the NOX test was to test for recirculation of gases from the power plant back into the fresh air supply system. This test was negative indicating chemicals were not recirculated into the secure area. The complaints involved carbon monoxide which "people could feel in their lungs". Evidently some flue gases from the hot water boiler were circulating in the HVAC system. The hallway from the HVAC area leads to the mess hall and when the doors were opened, these gases entered the third floor space. The gas boiler is only used as a backup and it is to be replaced by an electric boiler.

"Tests were made for dust and other chemicals in the fresh air ventilation system since fields are overhead. There's also smoke

from the fields above. They tested for pesticides using lists of chemicals employed for the past ten years. The question remains of what was used 20-30 years ago, and the accuracy of the list employed. In the environmental study they found nothing in individual rooms, but black soot was carried from the HVAC plant to the diffusers, which could result in carbon monoxide (CO). The tests results were negative for aldehydes, CO, and NOX.
With respect to cleaning procedures for the HVAC system, they are supposed to have monthly, quarterly, and yearly inspections: monthly, they clean the filter, oil the system, and generally check the operation; quarterly, they clean the unit and check the bearings; annually, they do a total cleanup, ducts, HVAC units, everything. They are years behind on all maintenance; about 6 on annual, 5 on quarterly, and 2 on monthly. A very small staff responsible for working with the HVAC. It is the facility engineer's responsibility to maintain all HVAC and electrical equipment, including cleaning. He supports the engineering officer. He keeps current by doing building walkthroughs 2-3 times a week, including the HVAC. He handles personnel complaints and equipment problems and tries to keep up with maintenance."

In response to a question about ventilation, tests are performed 4-5 times a year and in response to trouble calls. He uses an Alnore hood to test the total CFM coming out of each air handler and duct. The system was designed 20-40 years ago for a machine room environment. He has the initial system design for the total intended CFM, and current floor plans. As for the present condition, he would have to examine plans for the HVAC upgrade. He has everything available, but not readily accessible. With the raised flooring and floor air handlers, they are left with the old system. A good deal must be done just to maintain operations. There was a bad mold and mildew problem last year on the walls of one room. The room was dried out once, but still had bad odors. The maintenance staff cleaned the coil and the ducts. With 1-2 men, they could only spray it, but that wasn't good enough. After another cleaning, the odor from the coil was still noticeable. The third time, he and another person climbed in the space and found the evaporator coil was badly deteriorated. It was from lack of maintenance. The record indicated no annual maintenance since 1952 according to the latest inspection sticker. The building had been long empty so the U.S. Army Corps of Engineers wasn't required to act until the move in, about 1978.

Annual maintenance is needed, particularly on the ceiling type air handlers. They need to clean the ducts, replace deteriorated coils, and if it's cheaper to replace the unit than the coils, that should be done. In that room (with mold on the walls), conditions were unbearable for people. A 34 year old unit was not cleaned in 15 years. The coil was so rotted it was obvious that no maintenance had been done. Chunks of metal tubes and

fins were rotted. He's fortunate to be able to get filters changed. Another problem is inexperienced operators. For example, people threw away an ice machine unit which could have been saved for $80; it was turned in for salvage. Replacement cost is between $500 and $3000. This was due to an inexperienced crew. Qualified, experienced people are not available. DFE personnel have odd jobs as experience; a painter or routine maintenance. They can train them to operate the machine room and chillers, but they don't have the HVAC experience that required of a mechanic. Only one person qualifies as a mechanic.

The conversation then turned to staffing. He had a very small staff. He's entitled to have 10 men, 5 on shiftwork. He has 8 people now. It requires 2 people to look at trouble areas, for safety reasons. One person alone might fall through the ceiling because of deterioration. Five staff members are on shift work now. When the other 3 come off shift work, they take leave on days. The shift workers just operate the central plant office and machinery. They keep the chillers going, etc. This leaves one person available for maintenance. Even at 10, the manning is not enough to do the job.

When the interviewee arrived, they had no thermostat control of the air handlers. He had Honeywell thermostats installed on all three floors. His first goal was to control the building temperatures. They did that, although not as well as he would have liked. They had to centrally locate thermostats within an area so each one could take care of 5-6 offices. A sensor or temperature control is needed for individual rooms.

His second priority on arrival was to get the building under positive pressure. The building operated under negative pressure, pulling the fresh air through the access tunnel rather than the fresh air intake; they weren't getting any fresh air. Three years of the wrong type of operations led to algae buildup. Since they weren't properly filtering fresh air, they were getting moisture buildup, and exhaust fumes from vehicles using the tunnel over a period of three years. To deal with the problem, a baffling system was built for the exhaust. The building was initially designed for 60,000 CFM intake with 55,000 exhaust but when the galley exhaust was designed for the mess hall, they designed it for 30,000 CFM. He compensated for that with a fan and restricting the CFM. They finally started pulling air through the proper intake. As a result of the pressure problems, unfiltered dirt entered the building during the improper operation. This has never been cleaned out. It's still being recirculated.

There is a problem with mold. Once corrected in one place, it goes somewhere else; it jumps from floor to floor. His solution is to dry the area and reduce the fresh air supply. One problem is the system is designed for 80-100% fresh air through the fresh

air intake, whereas safe levels can be as low as 12%. (Ed comment: The implication is that the fresh air is bringing in a lot of humidity.) Whenever he deals with adjusting the pressure, he involves the headquarters engineers.

With respect to improvements in the HVAC system, "more systems are crammed into spaces as equipment is added. Typically individual stand-alone air handlers are added as retrofits. The problem is they are added to an existing central system. They work, but it is unclear why central HVAC and supplemental air handlers are needed. When raised floor space was employed, air handlers were added. They work perfectly for computer room environments. The new system will eliminate ceiling air handler units; this is expected to improve the situation. Some individual air handlers need repair but nobody wants to spend money on repairs because of the planned HVAC upgrade.

Two things are needed to help the building, and improve the overall health and environment. First, a reliable maintenance organization is required to track paperwork such as requests. Second, a filter conditioning system with an evaporator should be installed. It needs a huge coil, placed on the inside of the fresh air intake tunnel. This would condition the outside air before passing through the building. Currently, they don't condition the air. They filter it out, but the filters are very poor. They seldom are replaced; frequently remaining more than 6 months. A major problem is the fresh air intake tunnel. If the air were conditioned first, then the temperature level and relative humidity of the fresh air could be controlled. Now, they can't control the relative humidity. A major problem with any system as large as this one is moisture control.

With respect to balancing, air balancing equipment is not available. "With proper equipment it could be done, but it's hard to get, as are parts. It took more than one year to get an Alnore to measure CFM. It is possible is to try to get a reading close to the design level. A hood must be placed in the duct and actual CFM measured at each vent. This has never been done. No balancing has ever been performed with the air handlers. A maintenance crew is needed, the system should be balanced, and a conditioning coil is needed in the tunnel; then the current system could survive." When asked about the expense; "a $250 Alnore hood tester is required. To adjust the CFM properly two testers would be needed, then the air in every room could be balanced. I can't get the needed equipment unless there's a major emergency."

Air circulation problems were cited, attributed to open plan offices. Another recent problem involved a back-up in the sewage system onto the operations floor, with raw sewage in the floor drains (below the raised floor, fortunately). An environmental evaluation was performed, and a thorough area cleaning was

recommended, but no additional actions were taken. Air conditioning is a problem, the plumbing is old, the electrical systems unreliable (although the technical power is all right since there are five generators on station).

The planned air conditioning upgrade is badly needed, but went $4 million over budget. With limited floor space, over 9000 sq ft are used for air handlers. Egress is a concern, with fire exits too far away from the nearest safe hallway. In the morning one frequently finds black specks on the ceiling tiles and desks located near the air handlers.

C.5 Supervisory Civilian Analyst

"There are a variety of problems in the facility. There are long reaches of space to get to equipment. Cost weighs against significant human engineering features and changes. It is more economical to rack and stack equipment to save space, yet this is harder on the operator because he must get up and down 20 times or more to reach something on the top shelf. With respect to the timing of human factors input, when performed late, as a retrofit or after thought it is very expensive. We are not an equipment manufacturer but will put together a prototype system. Occasionally, as a result of general constraints the human engineering gets lost in the shuffle. As an example, at one of the old consoles it is very difficult to sit squarely in front of it; the operators tire quickly. The screen can't be moved to try to fix the offset problem. While this console is scheduled to be replaced, the new terminal also has problems.

It is a sad fact that we tend to temper the environment to accommodate equipment, rather than people. The collection floor is flooded with HVAC at a temperature often too low for comfort for the type of job done (namely, sitting behind a console). People are often cold; on evening and midshifts you see them wearing extra sweaters, etc."

The conversation switched to problems related to lighting and glare. The speaker noted that the new lights (with parabolic diffusers) are superb. There is a need to be able to turn off or mute the lighting system to meet equipment needs. Frequently they have had to damage the design to meet equipment needs. (The renovations are fine.) Because the lights were throwing too much light on the consoles, a number of lamps have been unplugged. Consequently someone who has to read material is adversely affected. Terminals may have glare problems created by fixtures; better fixture design might solve this problem, but the answer isn't clear yet. There are lighting problems in other areas; the major problems are the air conditioning and lighting systems. There are unexpected psychological impacts of design decisions. For example, during the energy crisis two or three years ago, they dimmed or disconnected lights to save energy. The

psychological impact was adverse. Too many people had underground tunnel syndrome from the dark, so they brightened the hallways. Good things could be done with colors to provide variety, etc. An underlying problem is that the facility was constructed and renovated in segments over many years. It was done piecemeal with little continuity. In the operations area there is a growing problem of crowding. There is yelling back and forth. Charts on the walls with acetate covering increase noise and reverberation making the noise/crowding problem more acute. Analysts need quiet, impossible to achieve with the floor configuration as is. There is a space crunch resulting in gripes from the analysts. Because of current space requirements, there is little expansion room. Conversations add to the overall noise and are further distracting because of their information content. Barriers are also created because th analysts are too far from the operations floor. The advantage of an open plan is its flexibility and economy of space.

One plan was to implement modular furniture so logical work areas could be sectioned off. There are many high dollar items waiting to be done. Many renovations are needed such as raised floors, dropped ceilings, etc., to make it a practical space. These are recognized problems. In addition there is a barrier between operations and analysis, as though they are two separate worlds. The facility is confronted with many problems. The tunnel itself is a major headache. It is a vehicular throughway - a traffic umbilical cord, used by trucks which belch diesel fuel. It can't be swept because it creates a 1/4 mile long dust cloud. Vacuumings are needed, but they can't get cleaners of proper size and power. A major requirement is a vacuum cleaner for the tunnel, an industrial size, to remove the dirt. If the tunnel is wet down, it takes three days to dry and you can smell the mold. The Fire Department wets it down every three months but it stays wet, and dirty, because of the vehicles.

In response to a question about putting a break area outside the facility. This is a given. People want to get out during the day, but many work 10-12 hours a day. It is difficult to get out. Some run or jog sometimes. A better jogging facility would be good. There is a need for a road or a jogging/bike path.

C.6 Conversations with individual operators (During Environmental measurements)

* The light levels are OK (at the low levels).
* The equipment is often slow.
* The noise levels are high.
* People asked for sound levels measurements at their headphones.
* It is cold, especially at night and people must wear sweaters.
* The chairs dirty the boots; they don't roll easily and then roll over the boots. They are also tippy, and lean backwards entirely too easy.

* There have been wet floors due to broken pipes. This shuts down operations and could damage equipment.
* Sniffles are common. Operators feel the air is bad, not enough oxygen.
* They would like to have a window or a simulated window to relieve the monotony.
* There are many broken chairs, with tape on the seats or broken arms or inadequate springs
* The parabolic louvers are very effective in the few places where used. The operators and supervisors want more of them, because it is easier to see the terminals.
* Lighting is a major issue. The troops repeatedly reported they cannot see the terminals when overhead lights are fully on. They even wore sun glasses to cut down on excess light. * The indoor air quality is much better since the smoking ban went into effect.

C.7 General Observations

* The Navy uses many fluorescent desk lamps which supplement the dim overhead lighting and are used for paper and pencil tasks. They are a bit large (about 12 in.) for the area and sometimes shine on the edge of the terminals. This approach (perhaps with a smaller luminaire) is quite effective, allowing the operator to see both the terminal and the paper task, while brightening up the overall space.

* Maintenance and regular cleaning are major problems in the analytical area, largely due to personnel increases and the subsequent need to rearrange furniture. This has resulted in rumpled and dirty carpets and a crowded office arrangement. Noise is a problem, much due to conversations. There are two major sources: people walking through the office areas carrying on conversations, and mission-driven consultation between individual analysts who have no place to go for their discussions. Printer noise is a major problem in some areas, as is noise from training films. Lighting levels are sometimes a problem for paper tasks with very low contrast. Analysts look at computer printouts, often printed with ribbons needing replacing (yet that is expensive and time consuming). Some workstations are very poorly lit. The overall light levels are higher, however, because both VDT and paper tasks are performed side by side.
* The desks on the operations floor are not placed sensibly with respect to light positions. Overhead lights are frequently behind the operator and display; images of the sources are visible on the displays. Lights are sometimes directly in front of operators so the bulb shines right into their eyes. This causes problems with adaptation and discomfort glare. Most bulbs do not have effective diffusers. The lighting appears to be very hit or miss, with many different types of diffusers and bulb used. Eggcrate, prismatic, parabolic, home made acrylic, and

bare bulbs appear side-by-side, as are a combination of cool white, warm white, and daylight bulbs, all in the same area.

APPENDIX D. Related Bibliographies

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

Because many military and civilian employees of the U.S. Army are required to work in environments unlike those experienced by most civilian workers, a project involving a comprehensive assessment of such environments was initiated. This assessment involves a two-phase effort in which the first phase consisted of a literature search, interviews with experts, site visits, and limited field environmental measurements. The second phase will include a comprehensive assessment of environmental conditions including lighting at selected military facilities. The present report documents findings from phase 1 including a detailed bibliography of target areas; lighting, stress and productivity, and shiftwork. It also includes preliminary results from a visit to two military field stations. During each visit, selected individuals, including supervisory, operational, analytical, and maintenance personnel, were interviewed to determine their view of the environmental conditions. At the same time, limited field measurements were made, including lighting, noise, temperature, humidity, and particle counts (at site 2 only). Preliminary data and recommendations are presented.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

automation; contrast; environmental assessment; indoor air quality; lighting; luminance; noise; post-occupancy evaluation; temperature; VDT's

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